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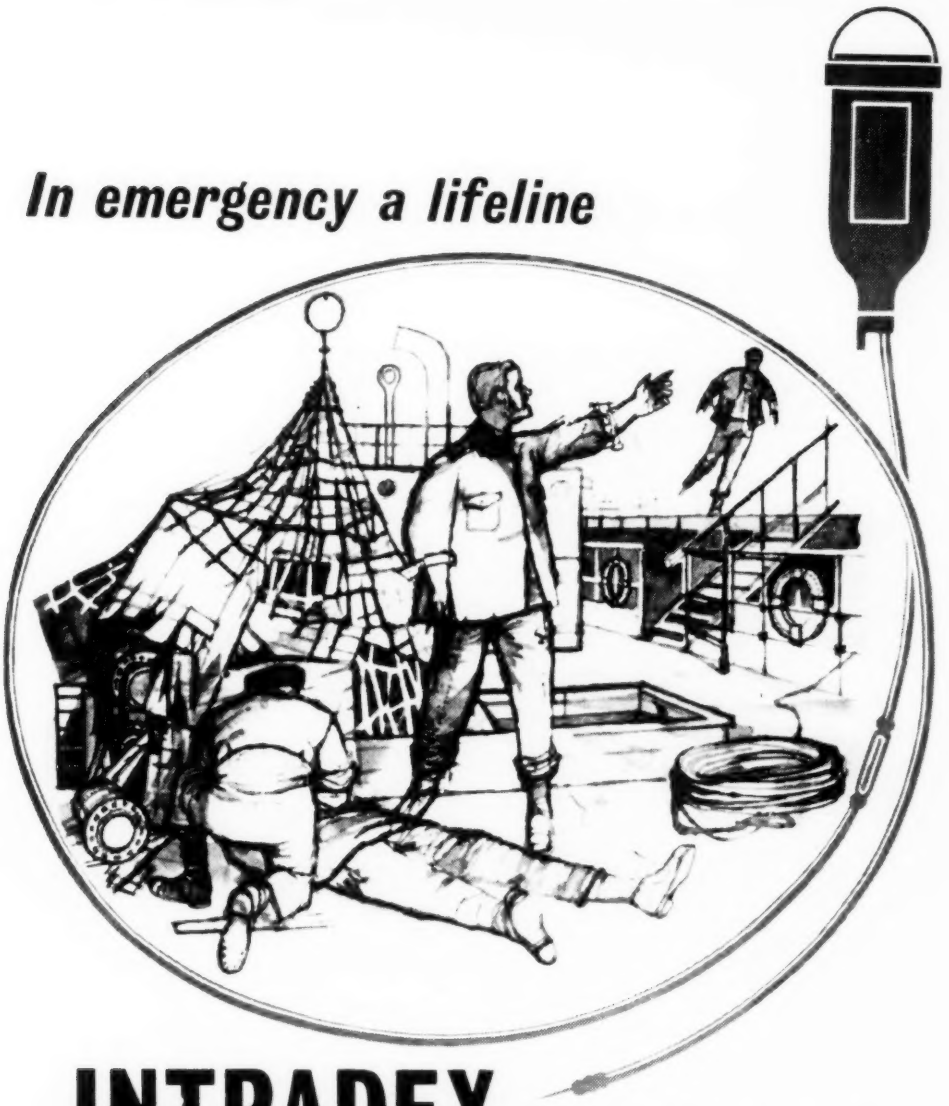

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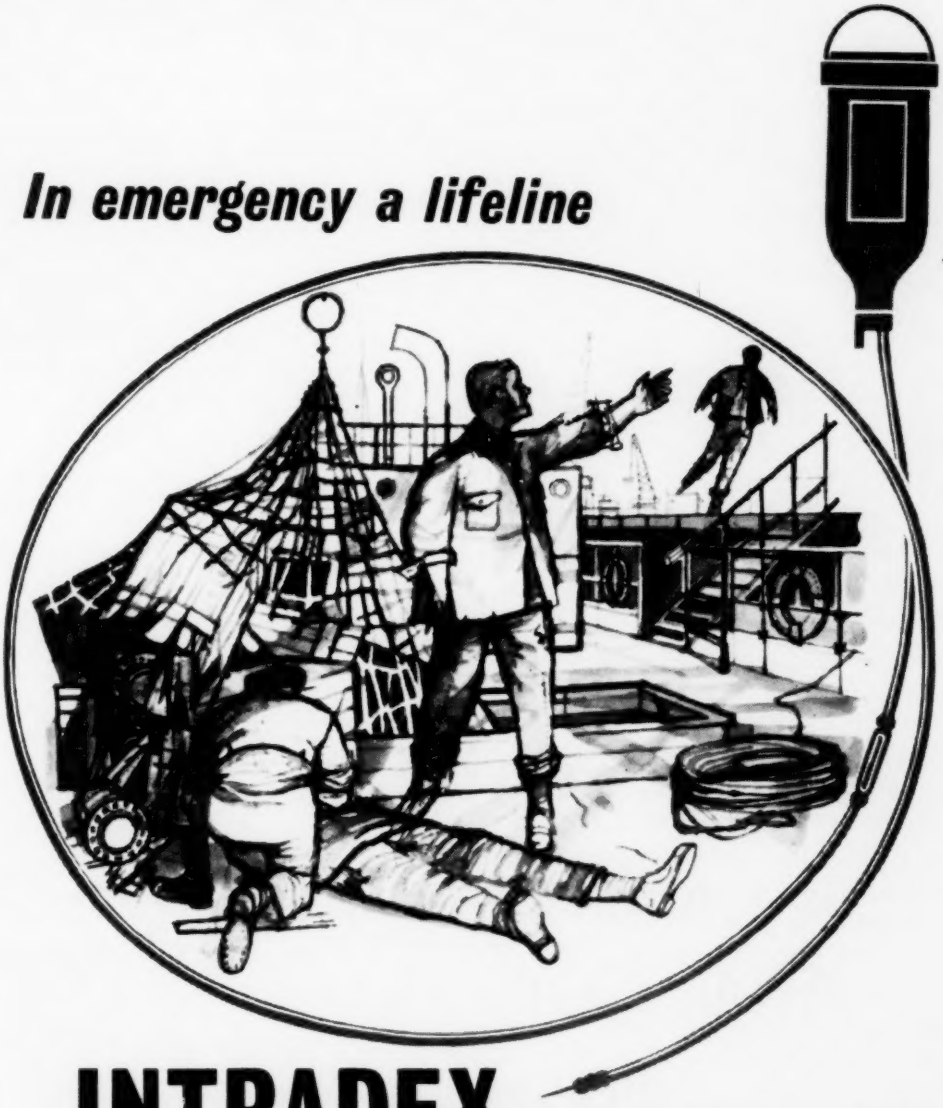

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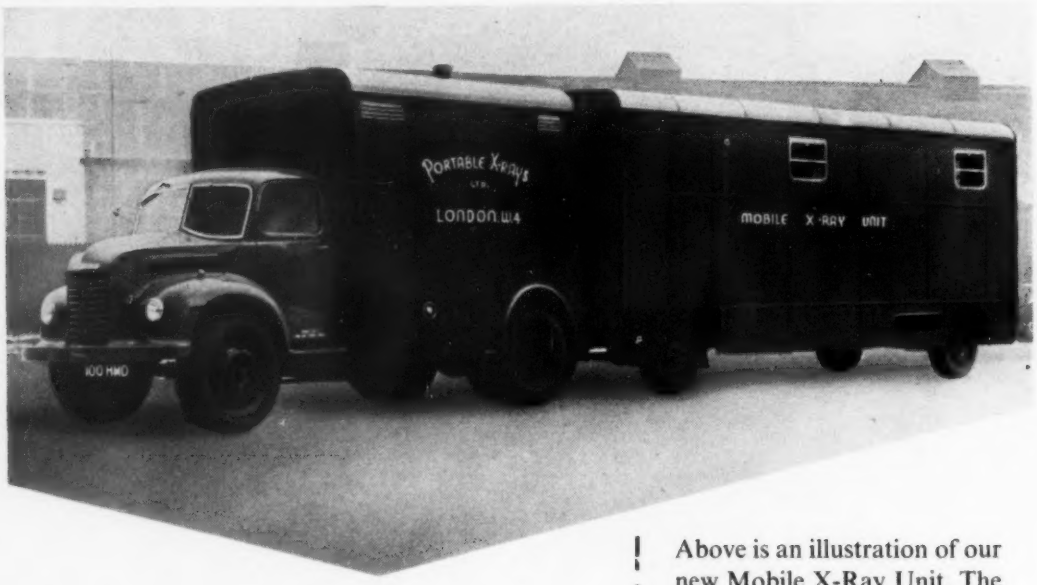

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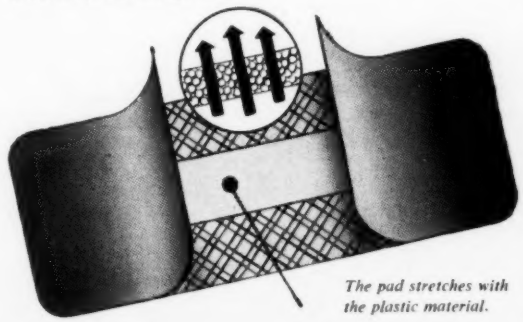

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Brit. J. industr. Med., 1958, **15**, 141.

THE ACCURACY OF OCCUPATIONAL VITAL STATISTICS

BY

M. A. HEASMAN,* F. D. K. LIDDELL, and D. D. REID

From the Department of Medical Statistics and Epidemiology, London School of Hygiene and Tropical Medicine, and the National Coal Board Medical Service

(RECEIVED FOR PUBLICATION MAY 23, 1958)

Statistics of mortality and morbidity in different occupational groups are essential for the effective practice of industrial medicine in the major industries. For coal-mining in 1950, the Registrar General (1954) reported a standardized mortality ratio for " hewers and getters ", *i.e.*, coalface workers, of 154; and the Ministry of Pensions and National Insurance (1955) reported that the rate of claims by coal-miners for sickness benefit was two and a half times the national average. The serious implications of these rates made a careful assessment of their accuracy essential. This paper discusses cooperative studies carried out by the General Register Office, the London School of Hygiene and Tropical Medicine, the Ministry of Pensions and National Insurance, and the National Coal Board Medical Service to examine the accuracy of the reporting of occupation on the various records concerned.

The numerators of occupational mortality and morbidity rates derive from job descriptions on death certificates and claims for sickness benefit respectively. The denominators of the rates come from entries of occupation on Census schedules. Errors may occur in both.

There are many diverse occupations in the coal-mining industry and each may have different names in the various coalfields. Many hundreds of names are listed in the instructions prepared by the General Register Office (1951) and are used for classifying occupations in all three sources of material for mortality and morbidity rates. The occupations are grouped into eight classes, given the codes 040 to 045, 047, and 049 as detailed below.

In the studies reported here, descriptions of occupations on death certificates, on claims for sickness benefit, and on Census schedules have been checked against the best available evidence of actual occupation obtainable from sources within the industry or outside it. The coding actually made on official documents has been compared with that which would have been made had the full and accurate descriptions of the jobs been available. The " official " occupational classes used by the General Register Office and the " independent " classification we have used are as follows:—

" Official " Classification	G.R.O. Code	" Independent " Classification
Subordinate superintending staff (including overmen, deputies, examiners, foremen)	040	I " Supervisors "
Workers below ground:—		
Coal-cutting and power-loading machine men	041	II " Faceworkers "
Hewers and getters (by hand) (including powered hand tool workers)	042	
Persons conveying material to the shaft	043	III " Other miners underground "*
Persons developing underground workings in rock	044	
Persons repairing and maintaining roads	045	
Other workers below ground	047	
Other workers above ground	049	IV " Surface mineworkers "
Occupations not specific to coal-mining	Other code numbers	V "General occupations"†

*Group III also contains a small number of stationary engine drivers, switchboard attendants, and oilers and greasers of engines and machinery, specified as working underground in mines (and allocated to G.R.O. Codes 910, 918, and 920).

†Group V contains men in occupations not specific to mining, *e.g.*, fitters, electricians, but employed in the coal-mining industry.

Inaccuracies in coding occupations may occur because of incorrect or inadequate description. In particular, where the entry " coal-miner " was made without any further detail, the G.R.O. instructions (based on a belief that most coal-miners have worked on the face at one time) state that such entries should be coded 042, *i.e.*, with " hewers and getters ". There is a further difficulty in that the classification of the individual mining occupations according to the eight codes given above is not ideal. Men doing the same work can be classified differently according to the various names given to that work. As one of

*Now of the General Register Office.

many examples, " pan turner " is coded 041, whereas " conveyor belt turner " is coded 043; yet the occupations are essentially the same.

Occupation on Death Certificates

Method of Inquiry.—The Registrar General made available information given in the death certificate for every man dying in England and Wales in 1955 and described on the certificate as a worker in the coal-mining industry. At the same time, the National Coal Board provided details of the last mining occupation of each man who died while still in the Board's employment. Both sets of data were sent to the London School of Hygiene where they were matched as far as possible. Where the deceased man had left National Coal Board employment some time before his death, the Mineworkers' Pension Fund and other records were searched to find the last colliery at which the man worked. When these sources failed, the medical officer of health of the district where the dead man lived was asked to visit the man's last known address to obtain this information. If the last colliery at which the man worked could not be determined, the medical officers of health usually provided some details of the man's last mining occupation. When the last colliery at which a man had been employed was ascertained, a statement of the job last done was obtained as before by enquiry at the pit.

The National Coal Board's (or medical officer of health's) description of the man's occupation is referred to in this paper as the " independent " occupational material in contrast to the " official " G.R.O. information. Both were coded according to the classification of occupations used by the General Register Office (1951). Those men who had left mining and taken up another occupation and were recorded as dying in that occupation were inevitably excluded from this investigation; the General Register Office would not know that these men had once been miners, nor would the National Coal Board know of their death.

During 1955, there occurred 4,533 deaths of men aged 20 to 64 who at death were either on the books of the National Coal Board or were described by the informant at death registration as being in a coal-mining occupation. Deaths of other men, *e.g.*, colliery clerks, were excluded if the occupational details given by both " official " and " independent " sources showed that they did not come within the occupational groups detailed above.

The sources from which the data were collected are shown in Table 1. Two descriptions of the mining occupation were provided in all but 139 cases (3·1%). Of these, 21 were reported independently by the National Coal Board, but no death certificates could be found. Similarly, for 118 deaths only the death certificates were available.

TABLE 1
SOURCES OF INFORMATION ON DEATHS

	No. of Men	%
Occupied Miners		
On N.C.B. colliery books and death certificate provided by G.R.O.	2,641	58·3
On N.C.B. colliery books, but no death certificate provided by G.R.O.	21	0·5
Employed by licensed mines and death certificate provided by G.R.O.	6	0·1
Classified by G.R.O. as occupied miner, but not in N.C.B. colliery occupation, *e.g.*, checkweighman employed by National Union of Mineworkers	11	0·2
Total occupied miners	2,679	59·1
Retired Miners		
Death certificates provided by G.R.O. and Occupational details provided by N.C.B.	1,293	28·5
Occupational details provided by medical officer of health:		
Complete information	254	5·6
Incomplete information	189	4·2
No further information obtainable	118	2·6
Total retired miners	1,854	40·9
TOTAL	4,533	100

Errors in Job Description of Occupied Men.—Table 2 compares the number of deaths among occupied men according to the " independent " and to the " official " information on occupation. There is reasonably close agreement between the counts for the " supervisors " and for " other miners underground "; but the two sources give quite contrary indications of the total number of deaths among " faceworkers " and " surface mine-workers ". The totals for " all mining occupations " are substantially the same and only 1·2% of the officially reported mining deaths were not in coal-mining occupations. Men whose last mining occupation was known from independent information to be on the surface have in many cases been described on death certificates either as " coal-miners " (when, under present G.R.O. convention, they are allocated to the faceworker classification) or as faceworkers.

TABLE 2
DISTRIBUTION OF OCCUPATIONS OF OCCUPIED MEN DYING IN 1955

Occupational Group	Number Reported		Percentage Difference
	"Official" Data (*a*)	"Independent" Data (*b*)	$\frac{(a)-(b)}{(a)}$
I: " Supervisors "	203	196	+ 3·4
II: " Faceworkers "	646	466	+ 27·9
III: " Other miners underground "	1,100	1,140	− 3·6
IV: "Surface mine-workers"	390	484	− 24·1
All "mining occupations"	2,339	2,286	+ 2·3
V: "General occupations"	319	372	− 16·6
Total	2,658*	2,658*	—

*Excludes the 21 deaths for which death certificates were not found by the General Register Office.

Occupational History of Retired Miners.—Men leaving the industry may take up other jobs, but may still be described as miners when their deaths are registered. To obtain some estimate of the frequency of such an event, a quasi random 10% sample of the 1,687 deaths among men known to have retired from a " mining occupation " was selected for special follow-up. Local medical officers of health were asked to obtain further information on the occupational history of the selected 168. Table 3 shows that at least 50 (30%) and perhaps up to 78 had in fact held other jobs since leaving the mines. The percentage was higher among faceworkers than among surface workers.

TABLE 3

SAMPLE SURVEY OF OCCUPATIONAL HISTORY OF RETIRED MINERS DYING IN 1955

	No. of Men	%
No further occupation	90	53·6
Known further occupation	50	29·8
No information about further occupation ..	28	16·7
Total	168	100

" Independent " information on the jobs of miners dying while still on colliery books but described on death certificates simply as " coal-miners " indicated that they were in fact distributed in proportion to the populations in each occupational group. The coding convention used by the General Register Office had classified these deaths as in the faceworker Group II (Code 042). Among the deaths of retired men, no independent information was available for 118; and for 189 the only statement given by the medical officer of health was " coal-miner ". These 307 deaths were therefore redistributed in proportion to the populations of retired men in each occupational group. On the basis of the sample, at least 30% of men were likely to have had a further occupation. The occupational group totals for retired miners were then adjusted to take these findings into account. The addition to the distribution given in Table 2 of the deaths among retired miners adjusted in these ways gives the final comparison of " official " and " independent " enumerations seen in Table 4. The total differs by 15%, and there is a very marked " promotion " effect into the " faceworker " and " supervisor " categories.

TABLE 4

DISTRIBUTION OF OCCUPATIONS OF OCCUPIED AND RETIRED MINERS DYING IN 1955

Occupational Group	No. Reported		Percentage Difference
	"Official" Data (*a*)	Adjusted "Independent" Data (*b*)	$\frac{(a)-(b)}{(a)}$
I: "Supervisors"	310	264	+ 14·8
II: "Faceworkers"	1,513	861	+ 43·1
III: "Other miners underground"	1,679	1,630	+ 2·9
IV: "Surface mineworkers"	585	722	− 23·4
All "mining occupations"	4,087*	3,477*	+ 14·9

*Excludes the 21 deaths for which death certificates could not be found by the General Register Office.

Occupations on Sickness Benefit Claims

Method of Enquiry.—With the agreement of the National Union of Mineworkers acting on behalf of the men, the Ministry of Pensions and National Insurance provided sufficient information for the Medical Service of the National Coal Board to check whether a sample of men who had spells of sickness ending in 1951 and whose descriptions of their occupations were coded as " coal-mining " by the Ministry, were in fact employed as miners when they became ill. On the advice of the Ministry, no subdivisions of coal-mining occupations have been made. The sample was of roughly 5% of all men who claimed benefit at local offices in Cumberland and in the London (Outer) Region. These offices cover the Cumberland and Kent coalfields whose isolation from other coalfields simplified the tracing of individuals. At all the collieries in the two coalfields the employment records were searched to discover whether each man in the sample was working there in 1951 and, if so, to define his occupation. The job descriptions supplied by the collieries were matched by the Medical Service against the coding made by the Ministry.

Errors in Job Description.—Of the 311 men in the sample, 275 (88%) were found by the local colliery enquiry to have been employed at the relevant time in 1951. A further nine (3%) were known at the collieries but had not been employed there when they made their claims. The remaining 27 (9%) could not be traced at the collieries. Table 5 gives

TABLE 5

OCCUPATIONAL HISTORY OF MEN CLAIMING SICKNESS BENEFIT IN 1951

	No. of Men	%
Men on colliery books		
Correctly ascribed to mining occupations	263	84·6
Incorrectly ascribed to mining occupations ..	12	3·9
Not on books at time of claim	9	2·9
Total men on colliery books	284	91·3
Men not found on colliery books		
Probably correctly coded to mining occupations ..	5	1·6
Probably incorrectly coded to mining occupations	16	5·1
Not otherwise classifiable	6	1·9
Total men not found	27	8·7
TOTAL	311	100

the results of these enquiries. The Ministry made a special examination of their records for the 15 men who had said they were coal-miners and were also shown on their contribution cards as employed in coal-mining but who could not be traced at the collieries.

Of the five men not found but probably correctly ascribed to mining occupations, several appear to have been miners holidaying in the area; one man's name was incorrectly recorded. The untraced 16, who were probably incorrectly described as miners, included eight whose industry was not recorded as coal-mining and three who claimed at offices in Greater London and whose occupations were common to industries other than coal-mining. It would thus appear that, out of the total of 311, probably 37 (12%) and up to 43 or possibly even 48 were incorrectly assigned to mining occupations. No estimate can be made of the numbers of men who claimed benefit while working in the mines but did not enter coal-mining as their occupation.

Occupations on Census Schedules

Method of Enquiry.—Occupational details of all men employed in April, 1951, at three collieries in Derbyshire, Kent, and Northumberland were sent to the General Register Office where a search was made of all the Census schedules for a population of nearly 100,000 in considerable areas surrounding the collieries. Even these areas did not cover all the addresses given by the collieries and a small number of men were excluded from the enquiry. Of the remainder, all but 148 were found and it was thus possible to compare, for 3,745 men, the occupations entered in the Census schedules with those provided by the collieries.

Errors in Job Description.—The allocation of individuals to the code groups used by the General Register Office on the basis of either " official " or " independent " data agreed in less than two-thirds of the comparisons (2,198 out of 3,745). A small number of disagreements (81) were due to errors of coding in the General Register Office. Inadequate descriptions on the Census schedules accounted for another 267 disagreements and more than half of these entries were of " coal-miner " without further specification. The great majority (1,199) of the disagreements arose because occupational descriptions from the two sources, although specific, were discrepant.

Among the population of 100,000, there were 105 men who entered on the Census schedules mining occupations at the particular collieries, but who were not, in fact, employed at those collieries at the time of the Census. There were also 22 men on the books of the collieries who were entered as unoccupied at the Census.

Table 6 gives the total counts of the mining populations in each broad group of the occupational classification. Allocation to the General Register Office codes has been based on occupational descriptions given (*a*) on Census schedules or (*b*) on colliery records. The 3,850 men in Column (*a*) include the 105 not on colliery books and exclude the 22 recorded on the census schedule as unoccupied. The 3,915 men in Column (*b*) include the 148 who were not found in the General Register Office's search of census records.

TABLE 6
DISTRIBUTIONS OF MINING POPULATIONS BY OCCUPATION

Occupational Group	Number of Men		Percentage Difference
	Census Schedules (*a*)	Colliery Records (*b*)	$\frac{(a)-(b)}{(a)}$
I: "Supervisors"	222	209	+ 5·9
II: "Faceworkers"	1,430	1,358	+ 5·0
III: "Other miners underground"	1,307	1,363	− 4·3
IV: "Surface mine-workers"	387	457	− 18·1
All "mining occupations"	3,346	3,387	− 1·2
V: "General occupations"	504	528	− 4·8
Total	3,850	3,915	− 1·7

Although the results from the three collieries were markedly different, the overall bias is one of " promotion " similar in nature but to a lesser degree than that found in death registration. At two of the collieries the proportions of entries on the Census schedules of " coal-miner " without further description were 11% and 4%; and the conventional coding of such entries as " faceworker " substantially increased the " promotion " effect. At the third colliery there was only one entry of this kind and the " promotion " effect was reversed.

Occupations of Retired Miners.—Particular difficulties arise among men who have left the mines, perhaps after a life time's work there, and taken other jobs. The General Register Office therefore searched the Census schedules for those men who died in 1955 and were known to have left the mining industry before the 1951 Census. Census records were found for 31 men who had taken other jobs before the Census. Of these, 20 were correct but 11 men had given their occupation incorrectly as mining. The Census population of " retired miners " is thus likely to have been slightly overestimated; but since " retired miners " form only 2% of the total population of occupied and retired miners between the ages of 20 and 64, this error is relatively unimportant.

Estimates of Mortality and Morbidity Experience

Our studies have shown that there are sources of error in both the numerators and denominators of occupational mortality and morbidity rates. These arise through mistakes in job description by informants, by coding all coal-miners without specified occupation as hewers and getters, and by the inclusion of some retired miners who have taken non-mining jobs among the " coal-miner " deaths. The errors in the total count of the mining population at the Census do not seem to be gross, but there are major errors in the counts of men in particular jobs. The extent of these errors varies so widely between the three collieries examined that we are unable to provide any reliable correcting factor.

The published figures of occupational mortality relate to occupied and retired men. Denominators for these rates can only be obtained from Census material and we have seen that this is somewhat in error for occupied men and may well be more inaccurate for retired men.

In Table 7 we have compared " official " estimates of miners' mortality with estimates based on the adjusted " independent " distribution, given in Table 4, and on unadjusted Census population data. The tentative nature of these mortality estimates must be emphasized. These " official " estimates are based on the 1949-53 recorded deaths.

TABLE 7

MORTALITY EXPERIENCE OF OCCUPIED AND RETIRED COAL-MINERS

(Standardized Mortality Ratios)

	1949–53	1955	
	* (*a*)	"Official" Data (*b*)	"Independent" Data (*c*)
I: "Supervisors"	88	100	86
II: "Face-workers"	148	142	81
III: "Other miners underground"	93	107	104
IV: "Surface mine-workers"	107	109	135
"All mining occupations"	112	117	100

*Registrar General's (1957) Decennial Supplement England and Wales, 1951. Occupational Mortality, Part II.

The agreement between the " official " figures for 1949-53 and 1955 (Columns (*a*) and (*b*)) is sufficiently close to suggest that there has been little change in the mortality experience over this period and that the methods used in this survey have been appropriate.

The ratios in Column (*c*) are the best estimates that we could make, adjusting for change of job among retired miners and after redistribution of deaths reported as occurring in men described simply as coal-miners. These figures have been based on the 1951 Census populations without any further adjustments. Although these rates cannot, therefore, be entirely reliable, the ranking of the occupational death rates from face to surface appears more likely to represent the true mortality experience than the greatly excessive rate for faceworkers shown in the official data.

Perhaps the most important finding is that the rate for all miners appears to be no greater than that of the general population.

We have also classified the deaths of occupied men according to the National Coal Board convention; except for under-officials, all men, including those in Group V, are allocated to their place of work. Standardized mortality ratios, based on populations by age and occupations supplied by the National Coal Board, are given in Table 8, where the rate for all miners is used as the standard.

TABLE 8

MORTALITY EXPERIENCE OF OCCUPIED MINERS IN 1955

(Standardized mortality ratios: All miners = 100)

Under-officials	88
Workers at the face	82
Workers elsewhere underground	102
Workers on the surface	122

It must be remembered that these estimates relate to occupied miners only and are comparisons within the mining industry; nevertheless, they are probably the most reliable indices of the relative mortality risks and they confirm the conclusions obtained from using the conventional methods on " independent " data.

The number of claims for sickness benefit made by coal-miners appears to have been overstated by about 15%. Adjustment by this amount would reduce the rate of claims for sickness benefit from two and a half times the national average to about 2·1 times, but no allowance has been made here for the inaccuracies in the Census population nor for any men who claimed benefit while occupied in coal-mining, but did not say so on their claim. It is thus likely that the true claim rate is close to the official figure.

Discussion of Results

The reported excess in mortality among " hewers and getters " in the coal-mines can be largely explained by errors in job description by informants at the time of registration of death and by the coding convention which puts all men described simply as " coal-miners " into the faceworker category. The multiplicity of terms describing similar jobs also causes confusion between " faceworkers " and " other miners underground ". Such errors are numerically important even for men who die while still on the books of the National Coal Board. Of all miners dying between the ages of 20 and 64, 41%

were described as " retired ", and among them greater difficulties arise. When a man retires he tends to regard his " former occupation " as the one in which he spent the greater part of his working life and it is only natural that he be similarly regarded by his relatives. This will affect the calculation of death rates in two ways. First, if the man's last job was in the mining industry but not at the coalface, he may be described either wrongly as a " hewer and getter " or as a " coal-miner ". In either event he will be coded as a faceworker and the hewers and getters' death rate will be correspondingly increased. If the man had held another job between leaving coal-mining and death and he was wrongly described as a worker in the coal industry, the death rate for all miners will be inflated. It has been shown that both these discrepancies have occurred.

There is some evidence that errors in the same direction occurred at the time of the Census, but they are unlikely to have such an effect on the calculation of death rates in mining occupations. To some extent, an overestimate of the face-worker population will compensate for the excessive reporting of deaths in that category.

Unfortunately, no precise correction for these sources of error could be made in this study, but the ranking of estimated death risks from face to surface workers is readily explicable by occupational selection, transfer, and wastage on physical grounds. There seems little or no evidence in favour of a death rate much above the national level; in fact, the faceworkers have a relatively favourable mortality rate compared with other underground and surface mine-workers. As long as death rates are based on the last occupation followed, this result is to be expected; a man who works at the coalface requires to be robust for the strenuous work involved. Only a man of good physique is likely to undertake such work; and should he become less fit he would be expected to move to lighter work.

The rate of claims to sickness benefit by miners reported by the Ministry of Pensions and National Insurance appears to be substantially correct. It is more than twice as great as the national average, but this does not mean that miners are twice as unhealthy as other employed men. Indeed, their spells of absence are shorter than average. The heavy physical demands of mining mean that an illness which would not incapacitate a clerk may seriously handicap a miner.

These results do not deny the risks to health inherent in arduous occupations such as coal-mining. But they do emphasize the urgency of current studies on occupational classification and on alternative measures of health hazards in relation to occupation.

Summary

A survey has been made of the accuracy of job description on records used for the calculation of indices of occupational mortality and morbidity.

The statement of last occupation in the mining industry made by the informant at death registration for men dying in 1955 has been compared with information obtained independently either from the National Coal Board or through local enquiries.

The statements of occupation on claims for sickness benefit and on the Census schedules made in 1951 in certain mining areas have been compared with the employment records at local collieries.

Evidence is presented which suggests that the death rate for " hewers and getters " reported by the Registrar General is inflated both by inaccurate descriptions by informants of men not employed as faceworkers as " hewers and getters " and the coding convention which assigns all men described simply as " coal-miners " to that category. Men who have taken up other jobs after retiring from mining occupations are also frequently described as " retired coal-miners ". On the other hand, similar inaccuracies in the Census population estimates for specific categories of mineworkers tend to reduce the net error in death rates.

The mortality rate of faceworkers estimated on the basis of the independent occupational description of deaths would appear to be less than that of other underground workers whose rate is, in turn, less than that of surface workers.

The death rate for all miners in 1955 was unlikely to be greater than the national rate for all males.

Taking the industry as a whole, the total counts of claims for sickness benefit and at the Census do not appear to be greatly in error. The reported excess of sickness claims of two and a half times the national average is likely to be substantially correct.

These studies were made possible by the financial support of the National Coal Board and the encouragement and cooperation of the General Register Office and the Ministry of Pensions and National Insurance. We would like to thank members of the staff of all these organizations, the Society of Medical Officers of Health, and the Medical Officers of Health in the mining areas. We are particularly grateful to Miss G. M. Jones, Mr. W. H. Leak, and to all those who have helped with the substantial amount of clerical and computational work.

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THE INFLUENCE OF CLOTHING ON THE PATTERN AND SEVERITY OF BURNS STUDIED IN SOME RECENT COLLIERY FIRE-DAMP IGNITIONS

BY

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Recent reports have demonstrated the important role of flammable clothing material in domestic burning accidents (Colebrook, Colebrook, Bull, and Jackson, 1956; Tempest, 1956). Such burns are extensive both in area and depth and they thus carry a high mortality. Indeed, some 90% of deaths from domestic burns are associated with the ignition of clothing. This matter is discussed in the report of the British Standards Institution (1957), which indicates the measures which could be taken to avoid such accidents. Happily these matters are attracting much attention in relation to domestic burns, but in industry little emphasis has so far been laid on the problem. Published references to the role of clothing in industrial burning accidents are few, but the Air Ministry Pamphlet No. 168 (1956) " First Aid and Early Treatment of Burns in the R.A.F." contains an excellent section on the protective value of clothes.

The fact that miners' clothing may catch fire in ignitions of fire-damp has many times been noted. For instance, in the report of H.M. Divisional Inspector for South-Western Division upon the explosion at Bedwas colliery in 1952 (Jones, 1953), we read that a small group of volunteers went inbye to explore the scene of the explosions and . . . extinguished several small fires where discarded articles of clothing were burning or smouldering. . . . In the top level they found the dead body of deputy A. G., badly burned with his clothing still on fire."

Again, in his report on the ignition at Glyncorrwg colliery in 1954, we read " . . . men came running down the [coal] face, some with their clothing on fire. . . ." and that later when the assistant manager and an overman explored " . . . they found articles of clothing on fire. . . ." (Jones, 1955).

Experience in Four Recent Colliery Ignitions

A recent series of underground gas ignitions has given us the opportunity to study in some detail the influences of clothing on burning injuries. During the period December, 1956, to June, 1957, four major accidents occurred in British coal-mines, resulting in burns to 13, 11, 19, and 23 men respectively.

The material for study in these 66 cases* consisted of detailed records of the extent, distribution, and severity of the burned areas in each case, together with necropsy findings in most of the 28 cases which proved fatal. Arrangements were made for recording in detail the clothing worn by each man at the time of the incident, and so far as possible the extent of burning suffered by these garments. In one incident, each item of clothing was examined by a panel of three doctors, including two of us, and an agreed record of the state of each set of clothing was made. Similar records were obtained for the clothing in the other three incidents, but in one of these (colliery S) our information on the extent of burning suffered by the clothing is incomplete. However, experience of the other incidents has enabled us to fill in, by inference, but with some assurance, these missing details.

Further information was obtained by questioning the patients, and other witnesses such as rescue and first-aid workers. Finally, the opinion of H.M. Inspectors of Mines has been sought as to the extent of the exposure to burning gas and material in these incidents in terms of duration and probable temperatures.

*Space forbids the detailed description or illustration of the burned skin and clothing in these cases. The complete case notes upon which this study has been based may be inspected on application to M. N. Tempest, F.R.C.S. (Ed.), St. Lawrence Hospital, Chepstow, Monmouthshire.

In general, there was exceedingly close agreement between the areas of skin and of overlying clothing which showed evidence of burning in all cases in this series. Very exceptionally cases occurred where this correspondence was incomplete; areas of skin were burned beneath clothing which was apparently intact, or the skin had escaped beneath clothing which showed evidence of burning. The former cases involved areas where hot gases could penetrate under a free edge of clothing, such as the arm and shoulder regions and shins. The latter demonstrated that even partly-burned clothing might yet give some protection to the skin beneath.

In all the incidents, exposure to burning gas had been of short duration—at most a matter of a few seconds.

Exposures at Collieries S, C, and B are likely to have been momentary—less than one second; at Colliery A it may have been for as long as 10 seconds. In none, as far as could be judged by expert examination of material evidence and the questioning of witnesses, had there been significant exposure to secondary conflagration, such as that of timber, belting, or coal. Estimates of the temperatures reached by burning gases in these incidents have been difficult to make, but 600° F. is required for the ignition of fire-damp and would be a minimum for burning gas, while exposure to spent gases following combustion will have been for longer periods but at lower temperatures.

Naturally, the severity of burns sustained by exposed areas of skin varies with both the duration of contact and temperature of the hot gases, as well as with the site and texture of the skin surface. Thus, for example, mucous membranes and the thin skin over the back of the hand and front of the neck suffer more severely than the tougher keratinized covering of the palms or soles.

Burns of Unclothed Areas.—In all these incidents, burns occurred commonly on the face, neck, hands, and forearms, these being areas usually unprotected by clothing: in this respect there is close similarity between burns in collieries and those occurring elsewhere. At Collieries C and S, however, working conditions were such that coal-face workers habitually wore only trousers, boots, and helmet while at work. In these men, therefore, " primary " burns of unclothed areas involved up to 70% of the total skin surface. (By " primary " burns we mean those which are caused by exposure to hot or incandescent gases or solid objects surrounding the subject, other than clothing. Burns caused by the ignition of garments are here considered as " secondary ".)

Working conditions were different at Collieries A and B; here more clothing was worn, though varying much according to the personal preferences of the men. Areas of primary burning in these men were accordingly less extensive. In primary burn cases where a shirt or singlet is worn, the outline of the clothing is left silhouetted on the skin (Fig. 1, *a* and *b*).

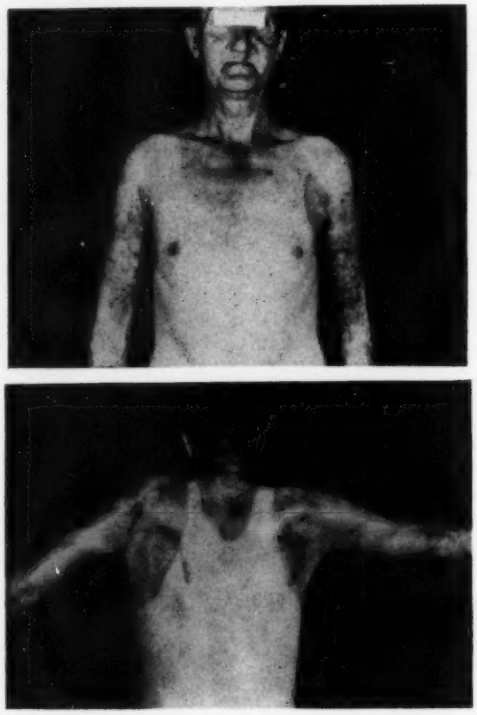

FIG. 1 (*a*) and (*b*).—This man was exposed to " flash " during a colliery ignition. The outline of his singlet can be clearly seen silhouetted on the trunk and shoulder. Note the lack of protection given to the axilla and upper arm by this type of garment. Extensive scarring in each axilla caused marked limitation of shoulder movement, especially on the left side.

Mention will be made below of the significance of primary burns in certain areas, including the respiratory tract. Here it will simply be remarked that such burns in colliery ignitions are rarely deep, usually involving only superficial layers of the dermis. Exceptions to this rule are found in the skin of forehead, nose, and ears; over the sternum and bony prominences in thin subjects; in the axillae and on the hands (Fig. 2). Colliery S provided nine examples of extensive primary burns, covering up to 45% of the skin surface. None of these was complicated by areas of full-thickness burning. The clothing of none was ignited. Among all the 66 cases in the whole series there occurred only two others (from Colliery B) where the primary burns were

TABLE 1

EXTENT OF SKIN BURNING IN MINERS OF FOUR COLLIERIES TO INDICATE PROTECTIVE QUALITIES OR OTHERWISE OF CLOTHING WORN

Colliery	Case No.	Age	Fatal (F) or Not Fatal (N/F)	Necropsy Findings and Other Injuries	Total Percentage of Skin Burned	Area (%) of Total Skin Surface Not Covered by Clothing		Area (%) of Total Skin Surface Covered by Clothing		Severely Burned beneath Burned Clothing
						Potentially Unprotected	Burned	Potentially Protected	Burned	
A	1	37	F	No necropsy	95	? 40	40	? 60	55	55
	2	69	F	No necropsy	98	? 40	40	? 60	58	58
	3	57	F	No necropsy	90	? 40	40	? 60	48	48
	4	27	F	No necropsy	90	? 40	40	? 60	48	48
	5	41	F	Pulmonary embolus	30	15	15	85	15	—
	6	39	N/F		30	15	12	85	18	—
	7	50	N/F		10	15	6	85	4	—
	8	43	N/F		30	15	15	85	15	—
	9	46	N/F		10	15	8	85	2	—
	10	36	F	Inspiratory burns; duodenal ulcer	60	15	15	85	45	40
	11	40	F	Inspiratory burns	60	40	15	60	45	35
	12	35	F	No necropsy Inspiratory burns	45	15	15	85	30	27
	13	18	F	No necropsy Inspiratory burns	50	15	12	85	38	20
B	1	33	N/F		25	15	15	85	10	5
	2	46	N/F		6	15	4	85	2	2
	3	54	N/F		2	15	2	85	0	0
	4	37	N/F	Laceration of scalp	18	15	11	85	7	5
	5	43	N/F		25	20	19	80	6	2
	6	53	N/F		12	15	12	85	0	0
	7	37	N/F		30	15	15	85	15	3
	8	36	F	Inspiratory burns Bronchopneumonia and duodenal ulcer Toxic kidneys and liver	40	20	19	80	21	18
	9	55	F	No necropsy Inspiratory burns	63	20	20	80	43	35
	10	41	F	Toxaemia; lungs congested and oedematous	50	20	17	80	33	25
	11	32	F	No necropsy Inspiratory burns	50	40	40	60	10	0
	12	48	F	No necropsy Inspiratory burns	45	20	15	80	30	15
	13	20	N/F		35	15	14	85	21	10
	14	26	N/F		31	15	13	85	18	8
	15	35	N/F		15	15	13	85	2	2
	16	28	F	Depressed fracture R. temporo-parietal Coronal suture open	18	15	10	85	8	6
	17	43	N/F		22	15	15	85	7	5
	18	42	N/F		18	15	10	85	8	6
	19	20	N/F	Concussion	5	15	5	85	0	0
S	1	52	N/F		35	10	6	90	29	? 20
	2	30	F	No necropsy report	65	50	40	50	25	? 20
	3	56	F	Inspiratory burns	45	50	45	50	0	0
	4	33	F	Inspiratory burns	60	50	42	50	18	? 10
	5	16	F	Inspiratory burns	50	15	14	85	36	? 30
	6	45	F	No necropsy report	45	50	42	50	3	? 0
	7	31	N/F		9	50	9	50	0	0
	8	46	N/F		25	50	25	50	0	0
	9	31	N/F		67	50	50	17	17	? 0
	10	23	N/F		28	50	20	50	8	0
	11	37	N/F		38	10	8	90	30	0
	12	46	N/F		50	50	30	50	20	0
	13	40	N/F		20	50	20	50	0	0
	14	31	N/F		45	50	40	50	5	0
	15	28	N/F		10	50	10	50	0	0
	16	29	N/F		32	50	42	50	8	0
	17	23	N/F		40	50	42	50	8	0
	18	51	N/F		10	50	10	50	0	0
	19	34	N/F		40	50	40	50	0	0
	20	29	N/F		45	50	45	50	0	0
	21	33	N/F		30	? 50	? 30	? 50	? 0	0
	22	18	N/F		50	50	50	50	0	0
	23	16	N/F		57	25	17	75	40	10
C	1	31	F	COHb 75% Inspiratory burns	31	10	5	90	26	12
	2	45	F	COHb. 70% Inspiratory burns	32	10	9	90	23	13
	3	40	F	COHb. 80% Inspiratory burns Duodenal ulcer	32	10	9	90	23	12
	4	23	F	COHb. 77% Inspiratory burns	33	10	10	90	23	14
	5	47	F	Inspiratory burns Toxaemia. Broncho-pneumonia	65	50	50	50	15	8
	6	36	F	Bronchopneumonia Toxaemia	55	10	10	90	45	12
	7	21	F	Bronchopneumonia Toxaemia	60	75	47	25	13	5
	8	29	F	Inspiratory burns Bronchopneumonia Toxaemia	35	30	30	70	5	5
	9	27	N/F		55	75	39	25	11	3
	10	19	N/F		31	30	15	70	16	10
	11	48	N/F		35	10	10	90	25	8

FIG. 2.—The late results of a flash burn showing very clearly the protection afforded by clothing. The victim was wearing a thick shirt and a muffler round his neck. The shirt sleeves caught fire at each elbow and the secondary burns at this site healed with considerable scar contracture. Note the protection given to the forearm which contrasts strikingly with the extensive keloidal scarring over the dorsum of the unprotected hand and fingers. Note also the protection given to the axilla and upper arm by garments with sleeves.

probably not complicated by burns from the subject's own ignited clothing.

Burns from Failure of Clothing Protection.—Table I shows the extent to which protection was afforded by the clothing worn by each subject in this series; care was taken to ascertain not only what clothing was worn, but how it was worn, for example, shirt sleeves rolled up, neck of shirt fastened, and so on. It will be seen that, except in Colliery S where the majority of men wore only trousers, socks, boots, and helmet, the extent of the burns in areas covered by clothing was greater in most cases than their extent in areas not so potentially protected. Thus evidently the clothing worn by the miners in this series fell far short of what is desirable for protection; and also, as we hope to show, of what is possible in practice. An example of superficial burns because clothing was not sufficiently protective is seen in Fig. 3.

Burns Due to Ignition of Clothing.—Clothing may not only fail to protect the skin from burns but by itself becoming ignited it may contribute very severe burns not only of underlying areas of skin but of other areas also.

It seemed reasonable to infer that burns beneath severely burned clothing in contact with the skin, if of greater severity than would have been expected had the area concerned been unclothed, could fairly be attributed to such contact with burning fabric. An attempt has therefore been made in Table 1 to assess the area in each case which could be said to have been burned in this way. It will be seen that the direct contribution to the injuries in these cases made by contact with burning clothing is by no means negligible—and in some cases is very considerable. Indeed, this component of the injuries may be said to have been responsible for the deaths of at least nine and possibly as many as 13 of the 28 fatal cases in this series; Case A10 (Fig. 4) illustrates this effect of contact with burning clothing.

Corroborative evidence of the importance of ignition of clothing in determining the extent and severity of burns came from study of the comparison between burns of the ventral and dorsal aspects of the bodies of the men in this series. The results of such an analysis are set out in Table 2, where it will be seen that except at Colliery B, there was a striking excess of burns on the dorsal aspects of the victims' bodies compared with their ventral aspects, and this despite a somewhat greater susceptibility of ventral skin to burns.

TABLE 2

DISTRIBUTION OF BURNS IN MEN FROM FOUR COLLIERIES

Colliery	Greatest on Ventral Aspects	Equal on Dorsal and Ventral Aspects	Greatest on Dorsal Aspects
A	0	6*	7
B	3	11	5
C	1	0	10
S	0	8	15
All collieries	4	25	37

*Including four cases with burns of 90 to 100% of body surface.

It seems impossible to account for such a preponderance of burns on the dorsal aspects of these men on the basis of their position at the time of the ignition. In one incident (Colliery A), for example, it is known that the men were grouped in a narrow circle around the point of ignition and probably all facing it yet none suffered more extensive burns on the ventral aspect. A more probable explanation is that some of the men had sufficient warning of danger to enable them to turn their backs to it.

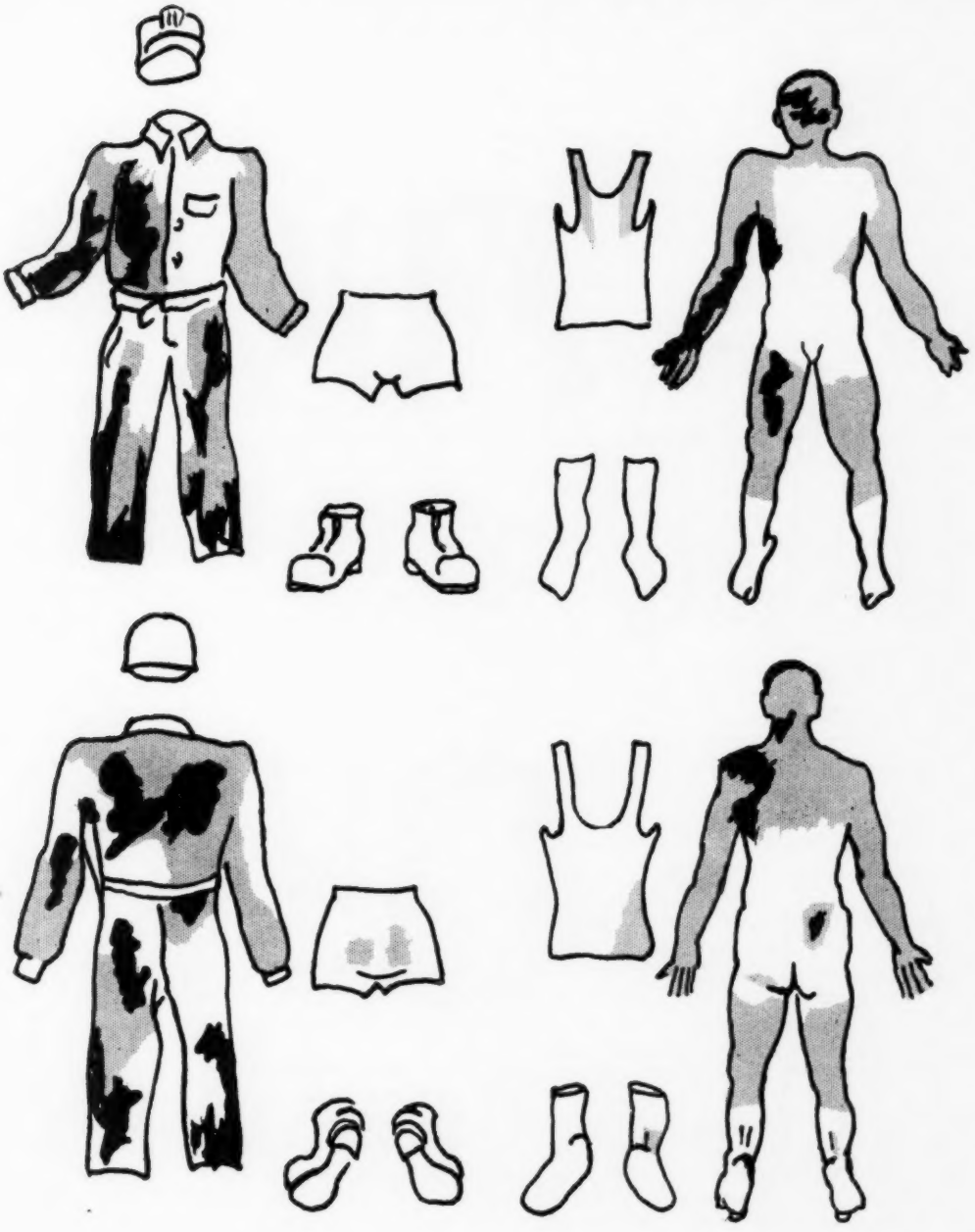

FIG. 3.—Drawings illustrating failure of clothing to protect the body in Case C.6.
Note protection afforded by undergarments, despite the failure of overalls due to their ignition and partial destruction. The burns of legs, arms, and upper trunk were of similar severity to those of unprotected areas, the hands, face and neck. Small areas, amounting to 12% of body surface, were deeply burned beneath the overalls. (Charring of clothing and full thickness burns are indicated by heavy shading. Lighter shading indicates superficial burning only of clothing or skin.)

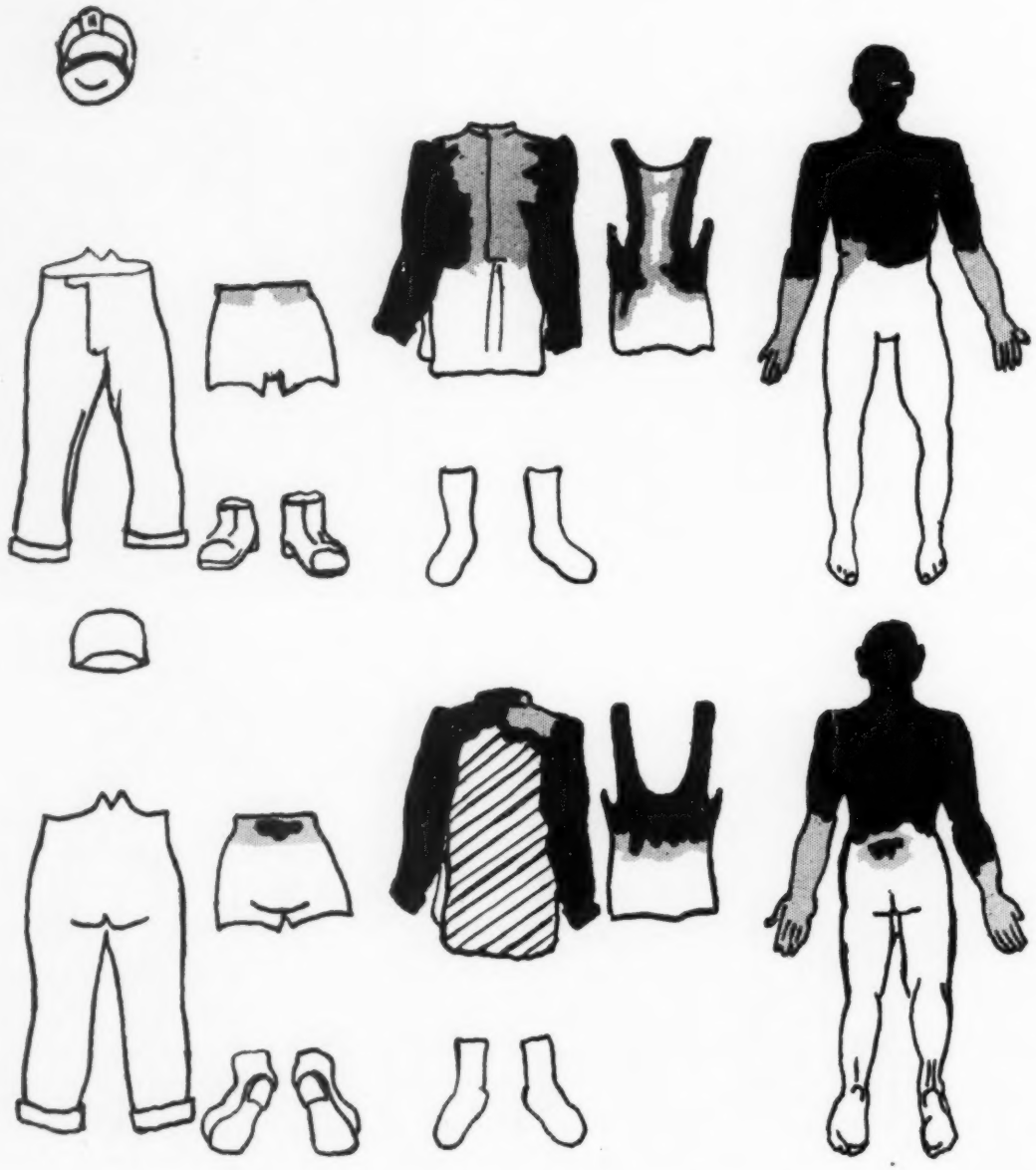

FIG. 4.—Drawings showing burns due to ignition of clothing in Case A.10.

Note the severity of the burns of upper arms and trunk in contrast to the superficial burning of forearms and hands. This man was working with his shirt sleeves rolled up above his elbows.

The shaded area of the back of the shirt was missing, having been burned away from the rest of the garment. It is likely that its tail would have been intact. (Charred areas indicated by heavy shading; superficial burning by lighter shading.)

This man had very severe inspiratory burns.

But the most probable explanation of this predominence of dorsal burns lies in the greater opportunity for observing and extinguishing clothing which is burning on the front of the body. Clothing on the back of trunk and limbs which has caught fire is unlikely to be noticed by the victim until he feels his flesh burning, and then is not easily extinguished without help.

The contribution of burning clothing to these injuries is not confined, however, to burns of the immediately underlying skin in contact with it. We have found it difficult to deduce with accuracy the extent to which flash burns have been aggravated by burning clothing in this series as a whole, but the cases of Colliery S provide some measure of this. In this episode there were 15 men with evidence of ignition of clothing (usually of trousers); facial burns occurred in all but two of these 13 men. In the eight men whose clothing showed no evidence of burning, there were only four with facial burns. It would seem natural to expect such aggravation to occur mainly in the upper parts of the body, including the face, neck, shoulders, and upper chest, as these would be most likely to be licked by flame from clothing alight on the upright subject. Other parts likely to be so affected are forearms and hands (see below) and the respiratory tract.

Inhalation Burns.—Inhalation burns are a well-known complication of explosions and fires in confined spaces; the classical case of the Coconut Grove disaster provided many examples (Aub, Pittman, and Brues, 1943; Beecher, 1943). Such burns are of special significance for oedema of the epithelium of the respiratory tract interferes with gaseous exchange; oxygenation of the tissues is already impaired after severe burns by circulatory collapse, excessive destruction of red cells by burning, and in some cases also poisoning by carbon monoxide. Many of those with inhalation burns develop respiratory infections which, despite antibiotics, oxygen therapy, and tracheotomy, often prove fatal.

Unfortunately owing to incomplete necropsy data it is not possible to offer more than an indication of the incidence of these burns in the present series. There was, however, evidence of inhalation burns in at least 21 of the 28 cases which proved fatal, and they were presumed to have been present on clinical grounds, or observed by laryngoscopy, in many of those who recovered.

It seems to us probable that in this type of burn, too, a considerable part may be played by the ignition of clothing, though proof of this is difficult. At Colliery A, the clothing of eight of the men who were grouped roughly in a circle around the point of ignition was extensively destroyed. Six of these are known to have suffered inhalation burns, and it is likely that the remaining two who died within minutes of the ignition would have exhibited such burns had examination been made at necropsy. There were no signs of inhalation burns in the five men whose clothing was much less extensively burned. Again, close correlation between inhalation burns and the extent of clothing destruction was seen in the cases from Colliery B but it was less close in cases from Collieries S and C.

So far as we are aware, no study has been reported elsewhere of the respiratory response of individuals to sudden exposure to flame. Reflex inhibition of respiratory movement is, however, provoked by any sudden danger signal, sometimes preceded by a partial inspiratory gasp. To account for the large number of inspiratory burns associated with mine gas ignitions, such strangled gasps would have usually to occur at the precise moment at which incandescent gas is passing the victim. It is a striking fact that although severe burns of the eyelids commonly occur in mine gas ignitions, burns of the conjunctivae are rare; indeed not one such burn occurred among the 66 men here considered. This fact is an indication of the efficacy of the blinking reflex as a protective mechanism, and suggests moreover that the eyes are usually kept closed or shielded throughout the danger period—perhaps to the detriment of other parts which may be burned by unextinguished clothing. It seems likely that a similar pattern of mechanisms protects also the respiratory tract, overcome only by severe anoxia: by then in most cases danger will probably have passed, except that from burning garments. However, it seems to us that the respiratory responses to danger should be studied.

From these considerations it seems probable that the majority of severe inhalation burns may be due to the inhalation of flame and hot gases arising from the ignited clothes worn by the subject. Those of lesser severity (probably more numerous than is commonly realized) could also be due to inhalation of spent gases after passage of the flame.

Carbon Monoxide Poisoning.—A frequent complication of injuries in those injured in underground fires and explosions is respiratory embarrassment due to carbon monoxide poisoning. Thus, for example, the four bodies recovered from the scene of the incident at Colliery C had blood saturations of carboxyhaemoglobin respectively of 75%, 70%, 80%, and 77%. All had extensive inspiratory burns, as well as extensive burns of the skin surfaces.

The clothing of all four men was also extensively burned, and it cannot be doubted that some at least

(*a*)

(*b*)

FIG. 5.—Extensive burns due to ignition of clothing.

Note the very extensive deep burn of the whole of the left upper extremity with the striking exception of the hand which was protected by a glove at the time of the accident (Case A.12).

FIG. 5 (*a*).—Profile and (*b*) dorsal views of hand burnt in a colliery ignition. The thin skin over the back of the hand and wrist is seriously damaged, whereas the tougher thicker skin over the palm is virtually undamaged.

of the carbon monoxide they breathed originated in their smouldering clothes. Unfortunately, it is rarely possible to obtain reliable carboxyhaemoglobin estimations in those rescued alive but burned; however, carboxyhaemoglobin in concentrations, over 30% was found in all but two of the nine least severely burned in Colliery A, and these included all the six men in this group who had inspiratory burns; the clothing of these seven men known to have been affected by carbon monoxide was severely burned.

Burns of Hands.—Flash burns of the hands are almost the rule in colliery ignitions. In a considerable number of cases in this series, however, hand burns were unusually severe; nearly all those whose hands were severely burned and who survived long enough to be questioned on the point, described their attempts to extinguish clothing on fire, either on themselves or their workmates. It cannot be doubted that such attempts are an important cause of burns on the hands and forearms.

The prevalence of burns of the hands is indicated by the fact that they occurred in all the 11 cases at Colliery C, in all but three of those at Colliery B, and in all but one of the men at Colliery A. This last man was the only one wearing gloves, but he sustained a burn of part of one hand due to a split in the glove covering it. At Colliery S, by contrast, nearly all the men escaped injury to their hands, thanks to the almost universal habit among men at this colliery of wearing gloves.

Needless to say, burns in this situation are of the greatest significance for the recovery of full working efficiency. They are the cause of prolonged incapacity in many burning accidents and may require protracted reconstructive operations (Fig. 5).

Burns of Scalp.—According to our information, all but one of the 66 men in this series was wearing a standard miner's safety helmet at the time of ignition of gas. Yet at Colliery B the hair of all 19 men injured was singed, nine having also extensive scalp burns, and a further three receiving a serious head injury, which was fatal in one case.

Extensive burns occurred in all cases also at Colliery A (Fig. 6), except in one man wearing a beret who alone escaped. A severe scalp burn involving the bony vault was the main injury in one of the fatal cases. Nine of the 11 men at Colliery C had scalp burns, the hair of the remaining two being severely singed. Only at Colliery S, apparently,

FIG. 6.—Full-thickness burn of the greater part of the scalp and the back of the neck, caused by a colliery ignition. Several similar examples were seen in the course of this survey and illustrate our contention that the standard miner's helmet gives inadequate protection against burns (Case A.8).

was protection to the scalp afforded by the safety helmet; here only one man suffered a burned scalp. There is evidently need to investigate further this widespread failure of " safety " helmets, including, if possible, the reasons for their success in the incident at Colliery S; here they may have remained on the heads of the men during the crucial period. The escape of these men's scalps may, however, have been for other, as yet unknown, reasons; for it was a feature of this incident that facial burns were fewer than usual.

Burns of Axilla.—Burns of this site are of special importance because of the frequency with which they are followed by troublesome scarring, leading to limitation or total prevention of movements at the shoulder joint.

Such burns occurred in a significant proportion of our cases, especially in those wearing singlets or vests without sleeves, and in those working stripped to the waist. It could be inferred from study of many of the burn diagrams that burns of this site were often due to attempts to protect the face with the forearms and hands, resulting in exposure to injury of this otherwise relatively inaccessible region.

Flammability of Miners' Clothing

The evidence presented above may be held to demonstrate the inadequacy of the clothing worn by these miners to provide protection from injury in these four incidents, which are probably representative of colliery gas ignitions. It seems likely that the clothing would have proved even less adequate to protect these men had they been involved in a general conflagration such as sometimes occurs underground.

Investigations have been made at certain burns centres in Britain, in collaboration with the Fire Research Station at Boreham Wood, Herts., to determine the correlation which exists between the flammability of the fabrics first ignited in domestic burning accidents and the extent and severity of the burns suffered by the wearer. Preliminary results of this work are indicated in the report of the British Standards Institution (1957) to which attention has already been drawn.

The flammability ratings of fabrics are based on the test devised by Lawson, Webster, and Gregsten (1955) and now incorporated in British Standard No. 476, part 2, 1955, " Flammability test for thin textile materials ". Briefly the rating is expressed by the time taken in seconds for flame to be propagated 100 inches along a vertically-hung test strip of the material. Domestic burns due to clothes catching fire are usually associated with flammability ratings of 15 to 80.

Flammability tests were kindly made for us by the Fire Research Station on all the items of clothing salvaged from the ignition at Colliery A. The cotton shirts and singlets examined all had ratings of 30 to 80, with the exception of one shirt of heavy cotton with a rating of 102, and a cotton singlet which was given a rating in excess of 200; yet both these garments were almost completely destroyed by fire. Various serge and drill trousers and two woollen pullovers gave ratings in excess of 200, as one might have expected from the nature and weight of such fabrics; yet even part of these garments was destroyed by fire. It is thus evident that the temperatures to which the men were exposed in this colliery ignition must have been considerable. As already mentioned, exposure to flame may have lasted up to about 10 seconds.

The extent to which permeation of miners' garments by fine coal dust and sweat may influence flammability of the fabrics concerned is a question which is being investigated on our behalf at present by the Fire Research Station, but we suspect that

these two factors will, in practice, usually cancel one another out.

Conclusions

The evidence we have obtained from study of these incidents has satisfied us that a major factor in determining the outcome of these and probably all similar colliery ignitions is the ignition of clothing. There was ample evidence of the protective value of clothing, provided this did not itself ignite. When that happened, as is usually the case with present-day garments worn underground, there was immediately risk of aggravation of the original primary burns, especially of the upper parts of the body; of burns of the hands and forearms sustained in attempts at extinguishing fired clothing; of inhalation burns; and possibly of added risk of carbon monoxide poisoning. If burning clothing remains in close proximity to skin, there is danger of very deep burns.

This leads us to conclude that some of the more serious consequences in loss of life and disablement of such colliery incidents could be avoided if more suitable clothing could be devised and worn by miners. From the point of view of protection from burns, working clothes should satisfy two requirements. These are, first, that so far as possible all vulnerable areas should be protected by clothing. Thus gloves should be worn, and the upper trunk should be protected by a shirt or vest, which should have at least short sleeves to give protection to the axillae; elbow-length sleeves would be preferable, The scalp should be protected by a properly designed helmet which will not easily become dislodged. Secondly, all outer garments should possess a high degree of resistance to ignition. This can be achieved in three ways: by use of naturally resistant fabrics such as wool or wool and nylon mixture (which avoids danger from static electrical charges); by using textiles rendered "flame-proof" by an acceptable chemical process; or finally, by the use of a flame-resistant rinse after laundering. Of these, the first and second appear to offer the most satisfactory solutions.

Tests are about to begin in the South Wales coalfield, at the instance of the Area Council of the National Union of Mineworkers, of working clothes thought to satisfy the above requirements. The garments will be tried out both for practicability and resistance to fire. It is to be hoped that following these tests it may be possible to induce increasing numbers of miners to adopt such clothing. In this there are of course numerous difficulties, including sometimes that of habituation to a style of clothing which is no longer demanded by present-day working onditions. More important, however, is the fact that miners provide their own working clothes, and usually wear their cast-off or partly outworn ordinary clothes at work. This practice raises difficulties because flame-proof garments are at present somewhat more expensive than ordinary ones.

Finally, there is the question of the helmets, which in three of these incidents so signally failed to afford protection to the men at the crucial moment. It seems highly desirable that the design of such helmets should be reviewed in the light of this finding, and that account should be taken of experience in other fields, such as aviation and motor cycling, so that the best possible protection can be afforded by the miner's helmet.

Summary

Experience of burning accidents affecting 66 men in four recent underground gas ignitions is reviewed.

Evidence is presented to show that while clothing has a valuable protective function, this is usually lessened in practice by the liability of the clothing now commonly worn by miners to ignite.

It is shown that many of the more extensive and severe burns are the result of clothes catching fire. This serious hazard of existing types of clothing is seen also in a probable increase in risk of burns of the respiratory tract, additional risk of burns of the hands, and perhaps also of carbon monoxide poisoning, in those whose clothing catches fire.

A striking feature of these incidents was the frequency with which deep burns of the scalp and head injuries occurred. It is suggested that the present type of miner's safety helmet needs consideration in the light of these findings and of experience with protective helmets used by other persons risking head injury.

Recommendations are made on the requirements for safer clothing than that now usually worn by miners to reduce the risk of serious injury by burning in colliery accidents.

We record our gratitude to the plastic surgeons who supplied us with valuable information about cases, especially Mr. D. Wynn Williams, Nottingham, and Mr. B. S. Crawford, Sheffield; and to the medical staff of Church Village Hospital, Glamorgan; Doncaster Royal Infirmary, Wharncliffe Hospital, Sheffield; Rotherham Hospital; Montagu Hospital, Mexborough; Wythenshawe Burns Unit, Manchester; Leigh Infirmary and Mansfield Hospital. We are grateful to Drs. G. B. Manning, C. M. Freezer, and A. J. N. Warrack, pathologists, for post-mortem reports.

Dr. R. W. Lawrence gave invaluable assistance in assessing and recording the state of the clothing of those admitted to Chepstow.

It is a pleasure to record our thanks also to Mr. D. I. Lawson, Assistant Director, Fire Research Station, D.S.I.R., for his interest and help in evaluating the

flammability of clothing worn by some of the men.

We should like to thank all those, too numerous to mention individually, who assisted our enquiries at the collieries, and members of the Inspectorate of Mines with whom these incidents have been discussed and who gave us much useful information.

Finally, we are indebted to Mr. A. L. Schofield, Surgeon to the Plastic Surgery Centre, St. Lawrence Hospital, Chepstow, for allowing us to use details of cases admitted under his care for the purposes of this study; and to the Ministry of Power for permission to publish this paper.

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THE APRIL (1958) ISSUE

The April (1958) issue contains the following papers:—

Respiratory Function during the Day in Cotton Workers: A Study in Byssinosis. By C. B. McKerrow, M. McDermott, J. C. Gilson, and R. S. F. Schilling.

A Histological Study of the Lungs in 52 Cases of Chronic Beryllium Disease. By W. Jones Williams.

The Effect of Diamond Dust Alone and Mixed with Quartz on the Lungs of Rats. By E. J. King, M. Yoganathan, and G. Nagelschmidt.

The Prevalence of Pulmonary Tuberculosis in a Northern Transvaal Copper Mine Related to the Importance of Pre-employment Radiographs. By G. E. Dalton.

Some Preliminary Thoughts on the Human Demands of Automation. By A. T. Welford.

A Clinical Study of Beat Knee. By J. T. Watkins, T. A. Hunt, R. H. P. Fernandez, and O. P. Edmonds.

The Paradox in the Treatment of Beat Knee. By R. H. P. Fernandez.

The Sedimentation Rate and Fragility of Human Erythrocytes *in vitro* after Exposure to Lead Chloride. By T. W. Clarkson and J. E. Kench.

The Effects of Bursts of Loud Noise on a Continuous Visual Task. By M. M. Woodhead.

A Method for the Determination of Trinitrotoluene in Air. By J. Mackay, K. W. Holmes, and R. E. Wilson.

Miscellanea:

Some Enquiries into the Toxicology of Zinc Stearate. By H. E. Harding.

A Human View of a Great Port. By M. W. Goldblatt.

The British Occupational Hygiene Society.

Book Reviews.

A number of copies are still available and may be obtained from the Publishing Manager, British Medical Association, Tavistock Square, W.C.1, price 17s. 6d.

Brit. J. industr. Med., 1958, **15**, 158.

THE TOXIC PROPERTIES OF DEMETON-METHYL ("METASYSTOX") AND SOME RELATED COMPOUNDS

BY

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The active ingredients in commercial demeton-methyl (" metasystox ") are the two isomers, 00-dimethyl 0-ethylthioethyl phosphorothionate (thionate isomer) and 00-dimethyl S-ethylthioethyl phosphorothiolate (thiolate isomer). By analogy with demeton (" systox "), which consists of a similar mixture of the 00-diethyl homologues and has been studied in plants by Heath, Park, Lickerish, and Edson (1953), and by Heath, Lane, and Park (1955), and in plants and animals by Fukuto, Metcalf, March, and Maxon (1955), it seemed likely that the action of demeton-methyl would be due mainly to the sulphoxide and sulphone of the thiolate, produced metabolically both in plants and animals. The demeton-methyl isomers, however, also undergo other reactions in water and on storage, giving small yields of sulphonium compounds of very high intravenous toxicity. The reactions involved are described by Heath and Vandekar (1957) and by Heath (1958) and are summarized here:

$$(MeO)_2PS.O.CH_2.CH_2.SEt \rightarrow \underset{\text{(thionate)}}{}$$
$$(MeO)_2POS^- + \overset{+}{CH_2.CH_2.SEt} \rightleftharpoons$$

$$(MeO)_2PO.S.CH_2.CH_2.SEt \quad \text{(thiolate)} \qquad (1)$$
$$(MeO)_2PO.S.CH_2.CH_2.SEt + \overset{+}{CH_2.CH_2.SEt} \rightarrow$$
$$(MeO)_2PO.S.CH_2.CH_2.\overset{+}{S}Et.CH_2CH_2.SEt. \quad \text{(unstable inhibitor)} \qquad (2)$$
$$2(MeO)_2.PO.S.CH_2.CH_2.SEt \rightarrow MeO.PO_2^-.CH_2.CH_2.SEt + (MeO)_2.PO.S.CH_2.CH_2.\overset{+}{S}Et.Me \quad \text{(methylsulphoniothiolate)} \qquad (3)$$

The yields of thiolate from the isomerization of the thionate (reaction 1) do not exceed 50% in water, as other reactions, giving inert products, take place.

In addition, the sulphoxide of the thiolate is partly converted to the thiolate on storage, though not apparently in solution, and then undergoes the reactions already described.

Some properties of the toxic compounds are given in Table 1. The thionate and the unstable inhibitor are both much less stable than the rest.

As a result of these properties and the reactions given, the demeton-methyl isomers show considerable increases in toxicity both in water and on storage undiluted.

In this paper toxic properties of commercial " metasystox " and of the aged (converted) samples of demeton-methyl isomers and their derivatives are recorded and results compared with those obtained for the purified compounds (Heath and Vandekar, 1957; Vandekar and Heath, 1957). The aim of such a comparison is to show how the toxicity data may vary if certain compounds are allowed to age by storage or if their toxicity is estimated at different times after dilution in water. Not only may the toxic dose change for certain compounds but the type and duration of symptoms produced after sublethal intravenous injection alter.

Chronic toxicity tests were carried out by feeding rats with different concentrations of two aged specimens of thiolate isomer and sulphoxide. For reasons given later it would appear that such converted compounds may play the most important role in producing any toxic hazard that may arise from the consumption of the food treated with " metasystox ". The degree of the reduction of the brain and erythrocyte cholinesterase activity was recorded and results were compared with those obtained in chronic feeding experiments with demeton (" systox ") (Barnes and Denz, 1954).

The results are recorded in some detail because they reveal further problems which may arise in

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assessing the toxicity of organo-phosphorus compounds with the property of inhibiting cholinesterase. The possibility of conversion and isomerization both before and after administration of these compounds to animals has been discussed before (Aldridge and Barnes, 1952), but in general this problem has received inadequate attention in the literature now growing up round toxicity studies on these compounds. These studies with demeton-methyl have revealed further examples of what may happen to some of these organo-phosphorus compounds.

Materials and Methods

Commercial " metasystox " was used in some experiments; it is stated by the makers to be a mixture of thionate and thiolate isomers in the proportion 70/30, diluted 1 : 1 with an emulsifier. The short names and formulae of the compounds* under investigation are shown in Table 1. All compounds were stored in the dark and some of them in the cold and dilutions were prepared immediately before use. Special precautions were taken in assessing the toxicity of the specimens of thionate isomer in order to reduce as much as possible the interval between the time of preparing dilutions and administering them to the animal.

Acute Toxicity Tests.—These were carried out on male and female albino rats from the laboratory stock. There were no significant differences in the responses of the two sexes to the compounds studied. Animals were kept under observation until all symptoms disappeared and for at least 24 hours. For oral doses a solution in water or 10% ethanol was administered. For injections, solutions in either water, propylene glycol, or ethanol were used or the undiluted compound was given by a microsyringe. When solvents were used, volumes of injections were kept within 0·1 ml./100 g. body weight in order to minimize any possible toxic effects from the solvent. The L.D.50 and 95% confidence limits were calculated by the method of Thompson and Weil (1952), using the tables for median-effective dose given by Weil (1952). This involves the use of four groups of four animals each with the dose levels related by a common factor.

Estimation of Recovery of Brain and Erythrocyte Cholinesterase Activity.—The organo-phosphorus compounds dissolved in saline were injected into the tail vein of male and female rats (200 to 250 g.). The doses were close to the L.D.50 and invariably produced severe symptoms. At selected times animals were killed by coal gas. At death, blood (5 to 8 ml.) was collected into 0·2 ml. of 1% heparin from the vena cava, and the erythrocytes were washed twice with cold buffer. Brain was dissected out, washed in buffer, blotted dry, weighed, and suspended in cold buffer (approximate concentration 70 mg./ml.) using a homogenizer of the Folley and Watson type. Buffer solution contained 0·0357 M-$NaHCO_3$, 0·164 M-NaCl, and 0·040 M-$MgCl_2$ and was freshly prepared from stock solutions and cooled to 5° C. before use.

Cholinesterase Activity.—Estimations were carried out in the Warburg apparatus at 37° C. with an atmosphere of 95% N_2 + 5% CO_2. Acetylcholine chloride was used as substrate with final concentration of 0·0138 M. One millilitre of brain suspension or the amount of washed erythrocytes corresponding to 0·5 ml. blood was generally used, but for highly inhibited samples 3 ml. of brain suspension or 1·5 ml. of blood was taken. Gassing and equilibration time in the bath did not exceed 15 minutes.

Anticholinesterase Activity.—The anticholinesterase activity of the specimens was determined with sheep erythrocyte cholinesterase for 30 minutes at 37° C., followed by the determination of the cholinesterase activity remaining (Aldridge, 1950).

The return of brain and erythrocyte cholinesterase activity was measured *in vitro* after selected times of incubation at 37° C. (Aldridge, 1953).

Persistence of Inhibitory Power of Serum.—The persistence of the inhibitory power of serum in rats was estimated at selected intervals after single intravenous injections when animals were killed by coal gas and blood collected as described above. Serum was separated and 2 ml. of serum was incubated with normal rat erythrocytes for one hour at 37° C. The erythrocytes were then washed twice with buffer and cholinesterase activity was estimated as above. The results are expressed as a percentage of the activity of erythrocytes treated in the same way with serum obtained from normal rats.

Chronic Feeding Experiments.—For the chronic feeding experiments solutions of the aged specimens of the thiolate isomer and sulphoxide were made up in arachis oil and added at the rate of 10 ml./kg. of powdered rat diet (M.R.C. diet 41). A weighed quantity was given daily to each cage. The food remaining next day was weighed so that the daily intake could be estimated. Animal weights were recorded regularly. All surviving animals were killed after six months by coal gas. Tissues for histology were fixed in Helly's fluid and stained by haematoxylin and eosin. Cholinesterase determinations were done on brain suspensions and washed erythrocytes as described above. The inhibitory power of serum was estimated; serum was incubated with normal erythrocytes for two hours instead of one hour as described above.

Results

Comparison between Aged and Purified Compounds.—Both thionate and thiolate isomers and the sulphoxide (Table 1) showed a significant increase in intravenous toxicity on ageing.

Different specimens of the same compounds when tested on their arrival already showed different L.D.50 values and after storage for several months they showed a further increase in toxicity. The toxicity increased similarly in the samples prepared or purified in our laboratory if stored for several months at room temperature. This is illustrated in Table 2 for one of the compounds in question,

*Kindly supplied by Messrs. Bayer of Leverkusen.

TABLE 1

DATA ON CHEMICAL AND BIOLOGICAL PROPERTIES OF ISOMERS, METABOLITES, AND TRANSFORMATION PRODUCTS OF DEMETON-METHYL (TAKEN FROM HEATH AND VANDEKAR, 1957, AND HEATH, 1958)

Short Name	Formula	Half Life in Water	Specimen	L.D.50°† (mg./kg.) in Female Rats		Signs of Poisoning after Intravenous Sublethal Doses		
				Intravenous	Oral	Type	Onset	Duration (hr.)
Thionate	$(MeO)_2PS.O.CH_2.CH_2.SEt$	9·2 min. at 37° C. 46 min. at 21·8° C.	(*a*) Pure	216 (—)	676 (—)	Anaesthetic	Immediate	~ 2
			(*b*) Aged (Spec. No. 5)	37·8 (32·4-44·0)	238 (168-267)	Cholinergic	Immediate	> 4
Thiolate	$(MeO)_2PO.S.CH_2.CH_2.SEt$	11 days at 37° C.	(*a*) Pure	64·6 (54·4-76·8)	62·5 (45·5-85·9)	Slight anaesthetic and cholinergic	Delayed	> 5
			(*b*) Aged (Spec. No. 6)	1·18 (1·05-1·34)	56·6 (—)	Cholinergic	Immediate	~ 1
Sulphoxide	$(MeO)_2PO.S.CH_2.CH_2.SO.Et$	22 days at 37° C.	(*a*) Pure	47·2• (—)	64·6 (54·4-76·8)	Cholinergic	Delayed	> 5
			(*b*) Aged (Spec. No. 3)	2·0• (1·6-2·5)	80 (54·8-117)	Cholinergic	Immediate	~ 1
Sulphone	$(MeO)_2PO.S.CH_2.CH_2.SO_2.Et$	18·5 days at 37° C.	(*a*) Pure	21·7 (17·5-27·0)	32·4 (27·3-38·5)	Cholinergic	Delayed	> 5
			(*b*) Aged	23·7	•	Cholinergic	Delayed	> 5
Methylsulphoniothiolate	$(MeO)_2PO.S.CH_2.CH_2.\overset{+}{S}EtMe$	13·4 days at 37° C.		0·062 (0·052-0·072)	9·8	Cholinergic	Immediate	1
Unstable Inhibitor	$(MeO)_2PO.S.CH_2.CH_2.\overset{+}{S}Et.CH_2.CH_2.SEt$	100 min. at 37° C.		0·002-0·01	—	Cholinergic	Immediate	

†95% confidence limits are given below L.D.50 value obtained on 16 rats. Where no value is given (—) all four rats died at twice the dose at which all four survived so that no limits could be calculated.
• = Male rats. Where the sensitivity of the sexes was compared no significant differences were observed.

TABLE 2

ESTIMATED L.D.50 VALUES IN RATS OF SEVERAL SPECIMENS OF SULPHOXIDE ON THEIR ARRIVAL OR PRODUCTION AND AFTER STORAGE IN THE DARK AT ROOM TEMPERATURE

Specimen*	Time of Determination	L.D.50 (mg./kg.)	
		Intravenous	Oral
No. 1	On arrival	32·7 ♀ (23·1–46·3)	—
	Seven months later	4·7 ♂ (–)	—
No. 2	On arrival	28·2 ♀ (23·0–34·2)	84·1 ♀ (59·5–119)
	Three-and-a-half months later	8·4 ♂ (–)	—
No. 3	On arrival	2·0 ♂ (1·6–2·5)	80·0 ♀ (54·8–117)
No. 4	Freshly prepared	47·2 ♂ (–)	64·6 ♀ (54·4–76·8)
	Six-and-a-half months later	15·4 ♂ (12·9–18·3)	—

*Specimens 1, 2, and 3 were obtained from Messrs. Bayer of Leverkusen (the date of production unknown). Specimen No. 4 was prepared in our laboratory (Heath and Vandekar, 1957).

sulphoxide. The sulphone, on the other hand, did not show any increase in toxicity.

Toxicity data, summarized in Table 1, where aged specimens are compared with purified compounds, show that the increase in toxicity is much more obvious when the intravenous toxicities are compared, the oral toxicities changing less markedly. Anticholinesterase activity *in vitro* parallels the high increase in intravenous toxicity.

On intravenous injection all the specimens except the purified thionate isomer produced typical signs of poisoning from cholinesterase inhibition, but there was a difference in the speed of onset and the duration of poisoning produced by the purified and the aged specimens. Pure specimens had a relatively low toxicity with a delayed onset and prolonged duration of the signs of poisoning. Their toxicity increased progressively on ageing with a more rapid onset and shorter duration of poisoning.

The high intravenous toxicity of an aged specimen will obviously depend on the presence of even the smallest amounts of the sulphonium compounds, which Heath and Vandekar (1957) showed were formed in those compounds which increased in toxicity on storage. In this work no attempt was made to distinguish between the methyl sulphoniothiolate and the unstable cholinesterase inhibitor. As shown in Table 1 the toxic characteristics of the aged thiolate isomer and the aged sulphoxide have approached those of the sulphonium derivatives. On the other hand, when aged specimens are tested orally, the presence of sulphonium derivatives is much less crucial because of their relatively low oral toxicity.

The intravenous injection of sublethal doses of purified thionate isomer produced a moderate anaesthetic effect. A lethal dose produced deep anaesthesia lasting for 20 minutes or more. Animals recovered slowly from anaesthesia but haemorrhagic pulmonary oedema developed and animals died from respiratory failure without showing typical

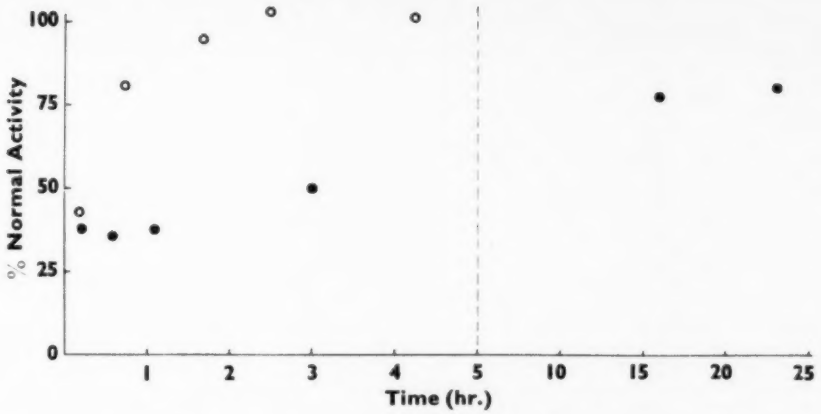

FIG. 1.—Cholinesterase activity of serum after single sublethal intravenous injection into male rats of an aged specimen of thiolate isomer (specimen No. 6) (○) and purified thiolate isomer (●). Each point represents one rat.

cholinergic symptoms. A slight anaesthetic effect was observed after intravenous injection of sublethal doses of purified thiolate isomer (Vandekar, 1957). Animals showed moderate brief incoordination followed by an interval of about 10 minutes when no obvious symptoms were present. Only then did typical cholinergic symptoms develop. When aged and more toxic specimens of thionate and thiolate isomers were injected intravenously only cholinergic symptoms were observed.

The effect of the persistence of the inhibitor in the body on the duration of symptoms and on the reactivation of cholinesterase *in vivo* has been shown recently (Vandekar and Heath, 1957) by a comparison of different dimethyl phosphate esters. Similar results have been obtained when the persistence of inhibitor in blood and the reactivation of erythrocytes were compared after sublethal intravenous injections of aged and purified specimens of thiolate isomer. The aged compound did not persist in the blood, and the activity of most of the inhibited erythrocyte cholinesterase returned rapidly. The purified compound, on the other hand, persisted in the blood for several hours and produced irreversible inhibition of most of the enzyme (Figs. 1 and 2). There was a further distinction between the aged and purified sample. While the purified thiolate isomer produced a considerable inhibition of brain cholinesterase, the aged sample inhibited the same enzyme only slightly (Fig. 2).

Effect of Dilution with Water.—Both thionate and thiolate isomers showed a rapid increase in intravenous toxicity when mixed with water. This is due to the formation of the toxic sulphonium derivatives at rates controlled by the concentration of the isomers

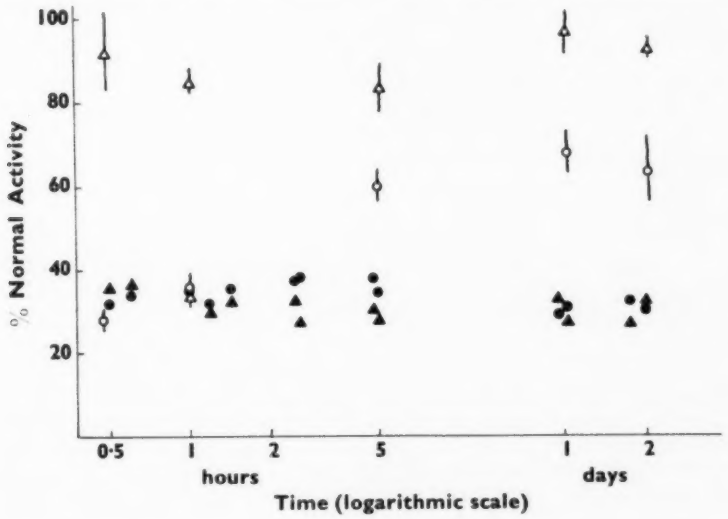

FIG. 2.—A comparison of the brain (△ ▲) and erythrocyte (○ ●) cholinesterase activity of rats at intervals up to two days after a single sublethal intravenous injection of:

(1) 1·2 mg./kg. of an aged specimen of the thiolate isomer (mean of four to six rats with 95% confidence limits);

(2) 50 mg./kg. of a purified specimen of the thiolate isomer (single rats);

Contrast the severe and sustained depression of brain cholinesterase activity after the purified specimen with the absence of inhibition in the brain after the aged specimen.

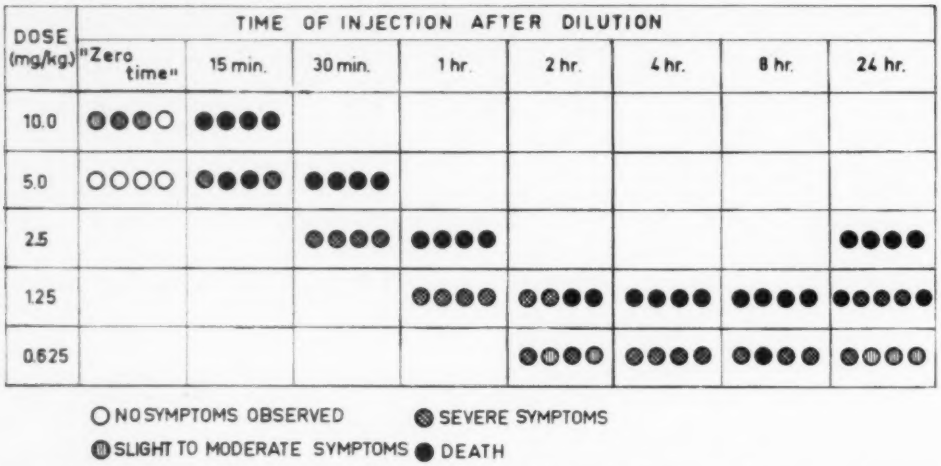

FIG. 3.—Graphic representation of the increase in intravenous toxicity of an aged specimen of thionate isomer (specimen No. 5) in aqueous solution. Thionate isomer was diluted in saline (1 mg./ml.) and injected in female rats (165-235 g.) at "zero time" and at selected intervals after being kept at room temperature (21° C.). Each circle represents one injected animal.

and the temperature (Heath and Vandekar, 1957). Table 3 shows differences in intravenous toxicities obtained before and after conversion in water of both thionate and thiolate isomers. The changes in toxicity after dilution in water were studied with an aged specimen of thionate isomer (specimen No. 5). A rapid increase in intravenous toxicity was observed when a suspension of 1 mg./ml. was left at room temperature (Fig. 3). The maximum toxicity (about 40 times higher than the original one) was found about four to eight hours after dilution; after 24 hours the toxicity decreased slowly, presumably as a result of hydrolysis of the unstable inhibitor (Heath, 1958). The rate of increase in the toxicity of the same specimen was rapid in 50% alcohol, methanol, or acetone, but was slowed if kept at 0° C. or if the dilution was increased.

TABLE 3

INCREASE IN INTRAVENOUS TOXICITY TO RATS OF THIONATE AND THIOLATE ISOMERS AFTER MIXING WITH WATER

Compound	Injected	Intravenous L.D.50 (mg./kg.)
Thionate isomer	Undiluted (by microsyringe)	216·2
	Diluted with water (1 mg./ml.) and left for 75 min. at 35° C.	2·5
Thiolate isomer	Undiluted (by microsyringe)	64·6
	Diluted with water (10 mg./ml.) and left for 24 hr. at 35° C.	2

The increase in the oral toxicity of both thionate and thiolate isomers after mixing with water was much less marked.

Neither sulphoxide nor sulphone showed any increase in the intravenous toxicity on storage in 1% aqueous solution for one day at room temperature.

Commercial "Metasystox".—In some preliminary experiments commercial "metasystox" was used. Injected as an aqueous solution (10 mg./ml.) intravenously in male rats, severe symptoms were produced in animals at 10 mg./kg. and death occurred in all injected animals at 15 mg./kg. The intravenous toxicity of the aqueous solution was considerably increased when left at room temperature. A freshly prepared solution with an L.D.50 of about 12 mg./kg. had an L.D.50 of 1 (0·5 to 2·0) mg./kg. after two hours.

Oral toxicity was determined both in fed and fasted female rats. The L.D.50 value was 226 mg./kg. and 113 mg./kg. respectively. Death was delayed in fed as compared with fasted rats receiving the same amounts of the freshly prepared solution (Table 4).

TABLE 4

ONSET OF DEATH IN FED AND FASTED FEMALE RATS AFTER ORAL ADMINISTRATION OF FRESH AND TWO-HOUR-OLD AQUEOUS SOLUTION OF COMMERCIAL "METASYSTOX"

Dose (mg./kg.)	Rats	Fresh Solution	Two-hour-old Solution
320	Fed	Death in 3½ to 5 hours	Death in 20 to 40 min.
	Fasted	Death in 30 to 40 min.	Death in about 15 min.
160	Fed	Survived	Death in 40 to 60 min.
	Fasted	Death in 50 to 60 min.	Death in 30 to 40 min.

An increase was found in the oral toxicity of the aqueous solution left for several hours at room

temperature, but it was not so pronounced as that observed in the intravenous toxicity described above. The survival time was considerably shorter when a solution that had been allowed to stand for two hours was administered (Table 4). This change in the toxic properties of " metasystox " solution in water may be explained on the basis of the observations with the purified isolated isomers (Heath and Vandekar, 1957) and aged specimens described above (see Fig. 3).

Chronic Toxicity Tests

Aged Specimen of Thiolate Isomer.—Four groups of six male albino rats were fed diets containing 0, 50, 100, and 200 p.p.m. of the aged specimen of thiolate isomer (specimen No. 6) for six months. Only the rats on 200 p.p.m. showed signs of poisoning. Slight tremors and fasciculations were observed occasionally within the first five weeks and one animal died during the fourth week. After the fifth week no further signs of this type were observed in spite of continued ingestion of the diet. One incidental death occurred among the control animals during the sixteenth week.

During the last month of the experiment dryness and scaliness of the tip of the tail was observed in three rats on 200 p.p.m. and in three rats on 100 p.p.m. At the beginning the tips were sore and a tendency to bleed was observed if the scaly surface was flaked off. Later the tips became completely dry, insensitive, and lacking flexibility. This change was progressing gradually and was more pronounced in the rats given 200 p.p.m. (Fig. 4).

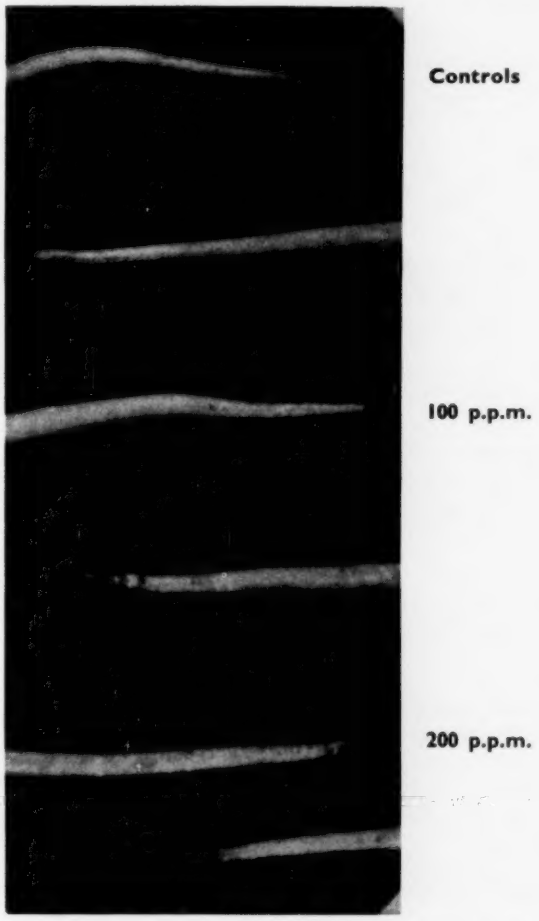

FIG. 4.—Tails of rats showing dryness and scaliness in those fed diets containing the aged specimen of thiolate isomer (specimen No. 6) for six months compared with two controls.

Growth curves are given in Fig. 5a, and show that rats on 100 and 200 p.p.m. were affected. Rats on 50 p.p.m. showed, on the contrary, better growth than controls.

The daily food intake of the rats was measured throughout the experiment and the mean values for the first two periods of three weeks and the next four periods of five weeks are given in Fig. 6a. The food intake was somewhat greater in all experimental animals than in the controls during the whole experiment, but this difference was more pronounced in the first 16 weeks. The greatest consumption of food was recorded in rats on 100 p.p.m. In spite of the high food intake the rats on 100 p.p.m. remained lighter than controls and much lighter than rats on 50 p.p.m. (Fig. 5a).

The animals appeared normal at necropsy. The liver, kidney, and adrenals were examined histologically. No pathological changes attributable to the action of thiolate isomer or related compounds could be detected.

Both brain and erythrocyte cholinesterase activities were considerably inhibited in rats on all levels of the inhibitor, showing less than 10% activity at 200 p.p.m. (Fig. 7a and b). In a certain number of samples the return of brain and erythrocyte cholinesterase activity was measured *in vitro* after selected times of incubation at 37° C. The results obtained indicated that more than 90% of inhibition was irreversible.

The inhibitory power of the serum was estimated and results are given in Fig. 8.

Aged Specimens of Sulphoxide.—Twenty-four male albino rats divided into four groups of six were given 0, 50, 100, and 200 p.p.m. of the aged specimen of sulphoxide (specimen No. 2) in their diet for six months. The rats on 100 and 200 p.p.m. showed slight tremor and were not as healthy as normal

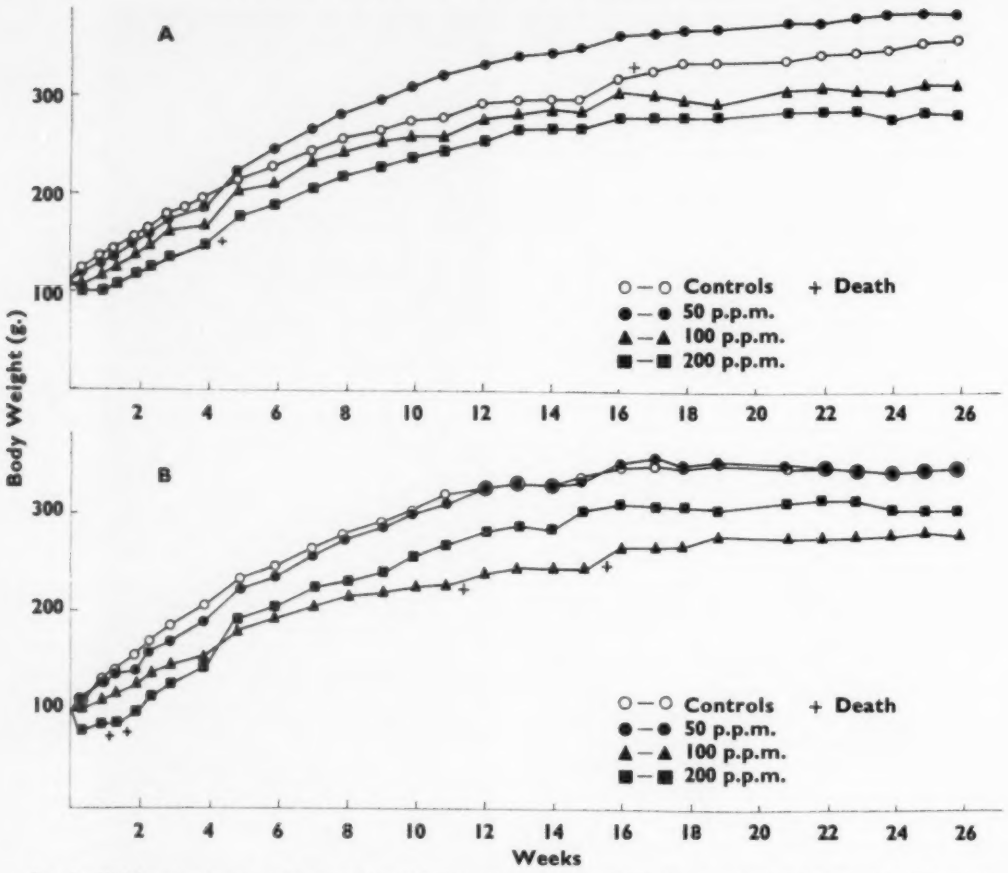

FIG. 5.—Weights of male rats on diets containing (A) aged thiolate isomer (specimen No. 6) and (B) aged sulphoxide (specimen No. 2)

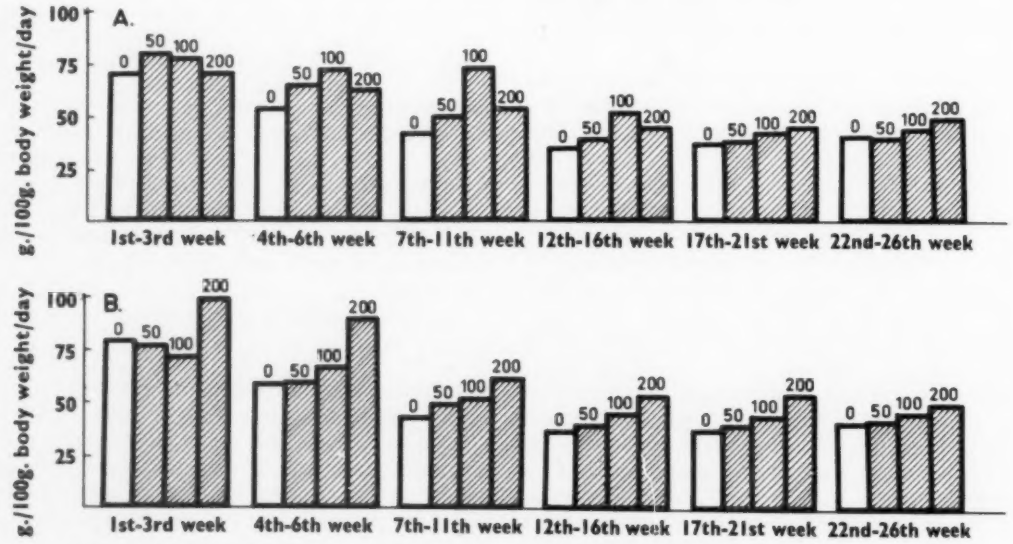

FIG. 6.—The daily food intake of rats on diets containing (A) aged thiolate isomer (specimen No. 6) and (B), aged sulphoxide (specimen No. 2). Each column is the mean daily intake for fixed periods of time expressed as g. of diet per 100 g. body weight.

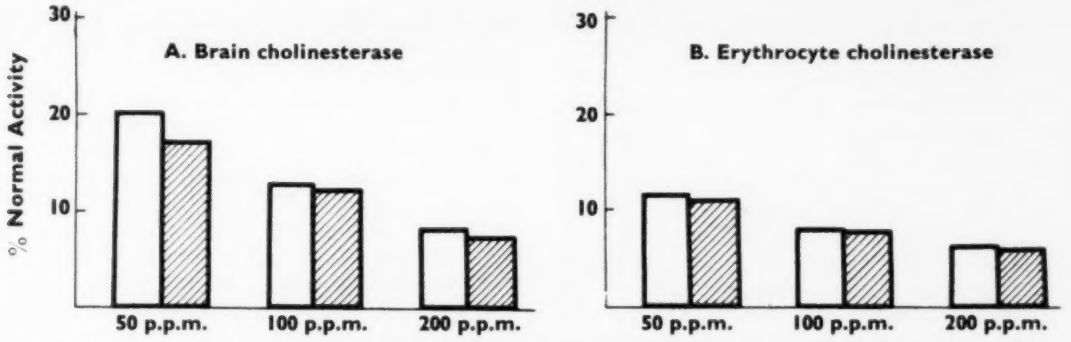

FIG. 7.—Cholinesterase activity of (A) brain and (B) red cells of male rats fed for six months on diets containing aged thiolate isomer (specimen No. 6) (white) and aged sulphoxide (specimen No. 2) (hatched). Each bar represents the mean of four to six rats.

during the first three weeks and two rats on 200 p.p.m. died during the second week of the experiment. After the first three weeks no signs indicative of cholinergic drug poisoning were observed in any group. Two incidental deaths occurred in the rats on 100 p.p.m. during the eleventh and fifteenth weeks.

Growth curves are given in Fig. 5b, and show that mean weights of rats on 50 p.p.m. did not differ from controls. The rats on 100 and 200 p.p.m. were affected, the latter more severely during the first month though thereafter the four surviving animals on 200 p.p.m. showed better growth than the rats on 100 p.p.m.

Means of food intake per 100 g. body weight for definite periods during the experiment (Fig. 6b) show that the food consumption in the rats on 200 p.p.m. was greater than in controls, and this difference was more pronounced in the first half of the experiment. In spite of the larger food intake the rats on 200 p.p.m. remained lighter than controls (Fig. 5b).

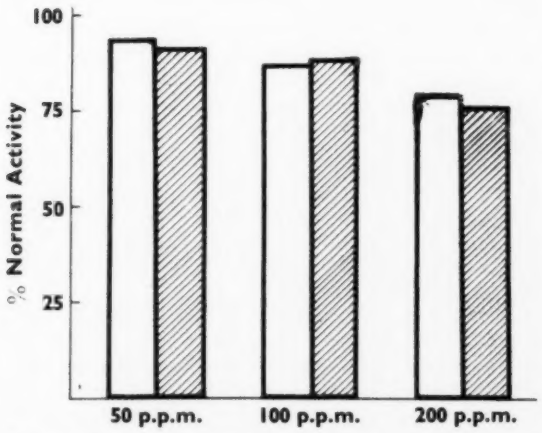

FIG. 8.—The inhibitory power of serum in male rats fed diets containing aged thiolate isomer (specimen No. 6) (white) and aged sulphoxide (specimen No. 2) (hatched). Each bar represents the mean of four rats. The serum was incubated at 37° C. with normal erythrocytes and, after washing, activity of erythrocyte cholinesterase estimated.

No pathological changes attributable to the action of sulphoxide or related compounds could be detected at necropsy or by histological examination of the liver, kidney, and adrenals.

The mean values for brain and blood cholinesterase activity after six months' feeding (Fig. 7a and b) show that they both were strongly inhibited at all three levels in the diet. At 200 p.p.m. less than 10% cholinesterase activity in brain and washed erythrocytes was found. The return of brain and erythrocyte cholinesterase was measured *in vitro* in several samples incubated at 37° C. The results indicated that more than 90% of inhibition was irreversible.

The results of the estimation of anticholinesterase activity of serum are given in Fig. 8, showing that more than 20% of inhibition of erythrocyte cholinesterase was produced with the serum obtained from the rats on 200 p.p.m.

Discussion

It was shown by Heath *et al.* (1953) and Wirth (1953) that the thiolate isomer is the more toxic isomer in commercial " systox ". Experiments with isolated dimethyl analogues (" metasystox " isomers) and related compounds showed that the thiolate isomer is more toxic than the thionate isomer, both showing relatively low toxicity when purified. It was also found that both isomers increased in toxicity on storage (or in water) by the formation of highly toxic sulphonium derivatives (Heath and Vandekar, 1957; Heath, 1957). The relatively high toxicity of the commercial " metasystox " product which was studied is consistent with the presence of

the very toxic sulphonium derivatives: other toxic impurities cannot be excluded.

A comparison of the aged and purified compounds revealed marked differences not only in the degree of toxicity but also in the type, onset, and duration of symptoms produced, these differences being much more pronounced after intravenous administration. Thus, while the purified thionate isomer in large doses produced anaesthesia and haemorrhagic pulmonary oedema with no cholinergic symptoms, and the purified thiolate isomer produced a slight anaesthetic effect followed by cholinergic symptoms, the aged specimens of both thionate and thiolate isomers in very small doses produced cholinergic symptoms only. Similar anaesthetic effects have been observed with other organo-phosphorus compounds with little or no anticholinesterase activity (Vandekar, 1957).

When sublethal single doses of the purified thiolate isomer or purified sulphoxide were injected intravenously prolonged symptoms were induced. The inhibitor was found to persist in the blood for several hours producing an almost complete irreversible inhibition of cholinesterase. On storage the toxic properties of the thiolate isomer and sulphoxide changed markedly and came to resemble those of the non-persistent dimethyl phosphate esters (Vandekar and Heath, 1957). Thus, the aged specimen of thiolate isomer produced symptoms of short duration and did not persist in the blood. Most of the inhibited erythrocyte cholinesterase recovered its activity rapidly and no significant inhibition of brain cholinesterase was produced, all the findings being similar to those obtained with sulphoniothiolate (Vandekar and Heath, 1957). This effect of ageing should also be borne in mind when chronic toxicity tests with purified (non-converted) specimens are planned.

A considerable increase was found in the toxicity of commercial " metasystox " after mixing it with water. As in the experiments with purified isomers (Heath and Vandekar, 1957), experiments with aged thionate and thiolate isomers showed that a rapid increase in intravenous toxicity followed the mixing with water. The change in oral toxicity was, however, much less pronounced. The fact that toxicity can be considerably increased either on storage or within the first few minutes after mixing with water can easily lead to difficulties in measuring the L.D.50. Thus one more problem in the assessment of the toxicity of organo-phosphorus insecticides may well be added to those already discussed by Aldridge and Barnes (1952).

Purified compounds showed relatively small differences between intravenous and oral L.D.50 values, whereas aged specimens or solutions in water as well as commercial " metasystox " showed a marked difference between intravenous and oral toxicities. This appears to be due to the presence of certain amounts of toxic sulphonium derivatives in aged or converted specimens. Methyl sulphonio-thiolate isolated by Heath and Vandekar (1957) showed a ratio of the intravenous to oral L.D.50 of about 1 : 100. Its relatively low oral toxicity may be partly due to the ionic charge which interferes with absorption. Other experiments with slow intravenous infusion of certain dimethyl phosphate esters showing a pronounced difference between intravenous and oral toxicity (Vandekar, unpublished results)* suggested that such a difference was due largely to variations in the rates of entry into general circulation. When the aged thiolate isomer (specimen No. 6) was examined in this way, a decrease in the rate of infusion from 4·6 mg./kg./hour to 3 mg./kg./hour resulted in a remarkable increase of tolerance from 1·8 mg./kg. to 25·2 mg./kg. It appears, therefore, that the higher values for the oral L.D.50 of both the commercial preparation and the individual aged or converted specimens are largely due to the " reducing-valve " action of the gastro-intestinal tract providing time for the body to take advantage of such defensive mechanisms as (*a*) reversal of inhibited enzyme (Aldridge, 1953); (*b*) the removal of the toxic sulphonium derivative either by demethylation to a less powerful inhibitor or by hydrolysis of inhibitor to non-toxic ionic products; and (*c*) elimination of the inhibitor through the kidney.

The fact that the drug first enters the portal system increases the opportunity for possible metabolism to take place in the liver. The greater sensitivity of fasted compared with fed rats given commercial " metasystox " orally also indicates the importance of the rate of absorption in determining toxicity. The comparison between intravenous and oral L.D.50 values of converted specimens (Tables 1 and 2) indicates that a rapid introduction of the drug into the body, *e.g.*, intravenous injection, is necessary in order to reveal the change in the toxic properties of these compounds when stored or diluted with water.

Mühlmann and Tietz (1956) have suggested that two toxic transformation products, the sulphoxide and sulphone, are formed in the plant sprayed with ^{32}P-labelled thiolate isomer of " metasystox ". The history of the commercial " metasystox " product from the factory to its degradation in the crop

*The effects of different rates of infusion into rats' jugular veins have been studied with certain cholinesterase inhibitors, and the results will be discussed in more detail elsewhere.

reveals a very large number of factors which may affect its toxicity. This has already been discussed by Heath and Vandekar (1957). Because of their rapid conversion to other products, the thionate and thiolate isomers *per se* will have little importance as residues in treated crops. Any hazard that might arise would be from the presence of their more toxic oxidative and sulphonium derivatives. The aged specimens of thiolate isomer (specimen No. 6) and sulphoxide (specimen No. 2), both containing some of these derivatives, were used in the long-term feeding experiments. The aged thiolate isomer, although much more toxic intravenously, when given to the animals regularly in the diet appeared to be somewhat less toxic than the aged sulphoxide. This greater toxicity of the sulphoxide was also seen in the acute oral toxicities. The degree of inhibition of erythrocyte and brain cholinesterase was proportional to the levels of the inhibitor mixed in the diet and was similar for both specimens. This depression of cholinesterase activity was considerable, though the animals in the later stages of experiments showed no signs of poisoning by an anticholinesterase agent. Similar observations were recorded by Barnes and Denz (1954) in rats fed demeton (" systox "). The observation that defective growth at the higher levels of feeding was associated with a higher food intake had also been noted in the case of demeton but not in the case of schradan (Barnes and Denz, 1954). This suggests that demeton-methyl and demeton (or their derivatives) may produce effects not seen with all cholinesterase inhibitors. The finding of the scaly tails in the rats on the highest levels of the aged thiolate isomer cannot be explained, but further supports the idea that effects additional to those on cholinesterase may be produced.

Summary

Aged specimens of the two isomers of demeton-methyl and its sulphoxide are compared with the purified compounds (Heath and Vandekar, 1957) and the effect of storage on the toxic properties of these compounds is illustrated. The effect of dilution in water on the toxic properties of the isomers, as well as commercial " metasystox " is examined.

The great increase in the toxicity of these materials either on storage or after dilution with water was clearly demonstrated by intravenous injections, whereas oral toxicity hardly revealed any change in toxicity. The dependence of the response to the drug on the rate of entry of the inhibitor into the general circulation is discussed.

Chronic feeding experiments were performed on the rats given diets containing 50, 100, and 200 p.p.m. of the aged specimen of thiolate isomer or sulphoxide for six months., Brain and erythrocyte cholinesterase activities were strongly inhibited both with the thiolate isomer and sulphoxide; and the degree of inhibition corresponded to the levels fed in the diet. In spite of considerable depression of cholinesterase activity, no signs of poisoning by an anticholinesterase agent in the later stages of experiments were observed. At the highest levels there was some depression of growth in spite of an increased food intake. Scaliness of the tails developed towards the end of the experiment. Anticholinesterase activity of serum in rats after an experiment lasting for six months was moderately pronounced and essentially the same for both compounds.

I wish to thank Dr. D. F. Heath for his collaboration throughout this work and for his help in preparing the account of the chemical changes. I am grateful to Mr. C. R. Kennedy for both valuable technical assistance and for running and keeping the records of the feeding experiments. I also thank Dr. J. M. Barnes and Dr. W. N. Aldridge for their interest in this work and Dr. P. N. Magee for the histological reports.

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TISSUE REACTIONS PRODUCED BY CALCIUM FLUORIDE IN THE LUNGS OF RATS

BY

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In a previous paper (King, Mohanty, Harrison, and Nagelschmidt, 1953), we showed that removal of an amorphous " high-solubility layer " from the surface of quartz particles with hydrofluoric acid appeared to enhance their fibrosis-producing capacity rather than to diminish it. Although the HF-treated quartz had been repeatedly washed, and even electro-dialyzed, it had at least as much, and usually more, fibrogenic capacity than the original quartz powder. We considered that this might be due to traces of hydrofluoric acid retained on the quartz particles. We thought it would be interesting, therefore, to test the effect of a relatively insoluble fluoride in the lungs of similar animals.

Lung changes have been reported by Luton and Champeix (1951) in men working with calcium fluoride in France. Their radiographic changes were described as typical of pneumoconiosis, and, indeed, similar to silicosis. The disease had evolved very rapidly, six of the 19 cases having developed it in less than two years. In another group of workers, severe lung disease was also found, but the radiographic shadows were atypical and different from those of silicosis. The dust inhaled by the first group of workers contained 60% of silica with 36% calcium fluoride and small amounts of aluminium and iron oxides. The second group inhaled dust which was mainly calcium fluoride (92-96%) with only 3-5% silica. Luton, Champeix, and Faure (1953) considered that calcium fluoride may by itself injure the lung tissue and produce lesions, and that it certainly enhances the action of silica, resulting in a severe and rapidly-developing form of pneumoconiosis.

Policard and Collet (1953) injected calcium fluoride intraperitoneally into rats, and found that after one to two months it gave a marked fibrotic reaction in the peritoneum, even more severe than that produced by quartz, but that, in contrast to quartz, it caused only an insignificant reaction in the lymph glands.

Experimental

Water-clear colourless crystals of calcium fluoride were ground to a fine powder and water-sedimented to give a 0·5-2μ fraction. The particle size distribution of the sample is given in Table 1. It contained less than 0·1% of silica, and had a solubility in water at room temperature of 1·6 mg. CaF_2 per 100 ml.

TABLE 1

PARTICLE SIZE DISTRIBUTION AND ANALYSIS OF CALCIUM FLUORIDE DUST

Size (μ)	Percentage by Number	Percentage by Mass
0·04 – 0·06	14·5	—
0·7 – 0·8	8·4	—
0·9 – 0·11	8·1	—
0·12 – 0·16	6·6	—
0·17 – 0·23	5·5	0·2
0·24 – 0·32	7·6	0·5
0·33 – 0·45	9·0	1·7
0·46 – 0·64	15·0	8·2
0·65 – 0·9	15·4	23·1
1·0 – 1·3	7·9	32·9
1·4 – 1·8	1·6	18·9
1·9 – 2·6	0·4	14·5
Dvs*	0·98	
MMD†	1·0	
σ‡	1·6	

* Dvs = volume surface diameter, $\frac{\Sigma nd^3}{\Sigma nd^2}$.

† MMD = Mass median diameter:
Size at 50% mass on cumulative size distribution curve.

‡ σ = geometrical standard deviation:
ratio of diameters having 50% and 16·5% mass or having 83·5% and 50% mass. These are 1·7 and 1·5, mean 1·6.

A group of 22 male rats of the black and white Medical Research Council strain (average weight 200 g.) was injected intratracheally with 50 mg. each of calcium fluoride. The animals were killed at regular intervals up to one year and the lung pathology studied. The collagen content of the lungs was determined in order to compare the values obtained with those from a group of rats injected intratracheally with 50 mg. of quartz (Stacy and King, 1954). The lymph glands were dissected and weighed.

The preparation of the dust suspension for injection was as follows: A sample of the dust, 1·5 g., was weighed into a glass tissue grinder, and 30 ml. of sterile physiological saline added. The dust particles dispersed easily.

The suspension was transferred to a bottle, sterilized by autoclaving for 20 minutes and then placed on a mechanical shaker until the time of injection.

The animals were lightly anaesthetized with ether, and were injected intratracheally with 1 ml. of the suspension (containing 50 mg. CaF_2). The injections were made, as described in the previous paper (King *et al.*, 1953), through a long blunt needle inserted through the mouth and down the trachea as far as the carina.

The fate of the rats, whether they died or were killed, and the duration of the experiment are shown in Table 2.

TABLE 2

PATHOLOGICAL CHANGES IN LUNGS OF RATS GIVEN 50 MG. CALCIUM FLUORIDE

Days of Survival	Mode of Death	Grade of Fibrosis
30	Killed (2)	2
39	Died (2)	2
41	Died (1)	2 max.
42	Died (1)	2 max.
70	Killed (2)	2 max.
81	Died (1)	3
90	Killed (2)	3*
91	Died (1)	2
105	Died (1)	2
150	Killed (1)	2
180	Killed (1)	2
207	Died (1)	—
210	Killed (1)	2
275	Killed (1)	2
300	Killed (1)	2
330	Killed (1)	4*
365	Killed (1)	3

* Sections reproduced in figures.
Numbers in brackets indicate number dead or killed.
Max. = maximum within the indicated grade of fibrosis
Grades of fibrosis: (1) lesions cellular, loose network of reticulin
(2) cellular, thick compact reticulin, with or without some collagen
(3) slightly cellular, mainly collagen
(4) completely acellular and wholly collagenous
(5) lesions acellular, collagenous and confluent

Most of the deaths took place within the first 90 days. Two animals were killed each month until this time, thereafter one animal.

The techniques of removing the lungs, fixation, embedding, and sectioning were as previously described (King *et al.*, 1953). Blocks were selected through the long axes of both lungs at the level of the hilum and sections were stained with haematoxylin and eosin, impregnated with silver for reticulin and collagen, and micro-incinerated to reveal the distribution of the dust.

Collagen analyses were performed on the dried powdered remnants of each pair of lungs, to which were added the remainders of the blocks and their trimmings after suitably de-waxing with benzene. Results have been expressed as milligrams of collagen contained in each pair of lungs. These figures are comparable, and are substantially correct, since only very small proportions of the lungs were lost to analysis by inclusion in the sections.

Results

Subpleural collections of dust were seen as greyish-white foci, situated chiefly over the dorsal aspect of the lungs, early in the experiment. The hilar lymph nodes were enlarged to four or five times normal size. By 40 days small areas of fibrosis were seen scattered over both lungs. By 90 days they were 2 to 3mm. in diameter, and were hard. The animals which died during the first 90 days showed evidence of bronchopneumonic consolidation, widespread necrosis, and appearances simulating an acute pulmonary infection; but Gram-staining did not reveal the presence of organisms. The lymph nodes were greatly increased in size and were about six times normal at 110 days. From this time onward there appeared to be a regression in the size of the lymph nodes, and at one year they were two or three times the normal size and very firm. Average weights of the nodes are given in Table 3 together with those of control rats, (*a*) without dust and (*b*) with 50 mg. of quartz.

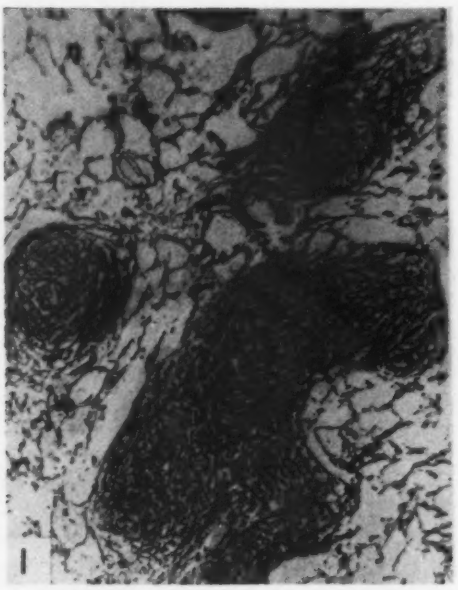
TABLE 3

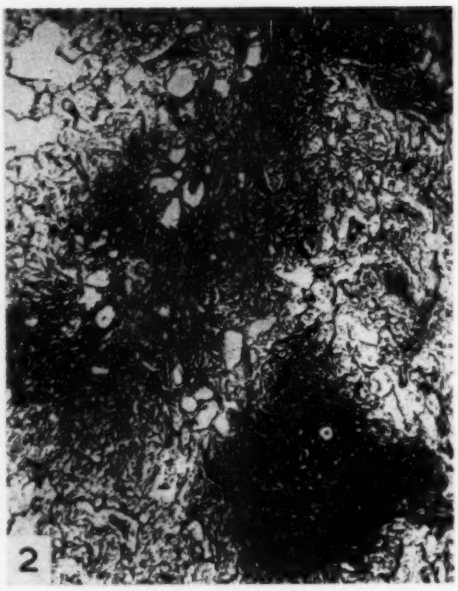
FRESH WEIGHTS OF LYMPH NODES IN CaF_2 EXPERIMENT COMPARED WITH WEIGHTS WITH DOSE OF 50 MG. QUARTZ AND WITHOUT DUST

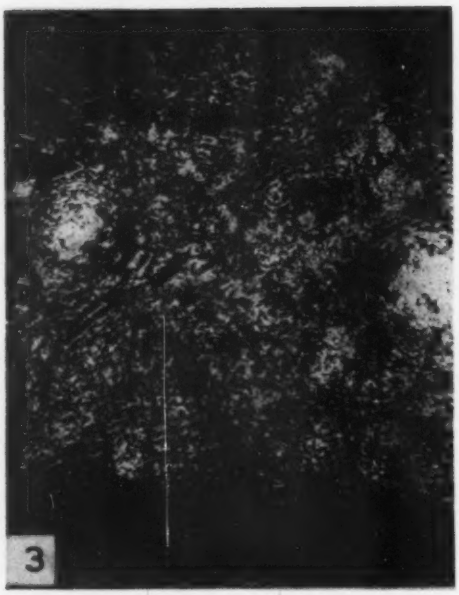
Time after Injection (days)	Node Weight (mg.)		
	CaF_2	Quartz	No Dust
0– 90	260 (12)*	240 (9)	32 (8)
90–210	180 (4)	660 (12)	35 (14)
270–365	80 (4)	1,100 (3)	—

*Numbers in brackets are number of rats.

Microscopically, there appeared to be a good dust cell response by 30 days and a marked reaction in the peribronchial lymphoid tissue. Small discrete lesions of irregular shape were mainly perivascular or peribronchial. But a large proportion of the dust was lying free in clumps in the alveoli. At both 30 and 40 days the lesions were seen to contain a compact network of reticulin with some collagen. Besides the fibrotic lesions some of the lungs showed evidence of patchy consolidation, with widespread necrosis and infiltration with acute inflammatory cells. No microorganisms could be found. This condition was particularly evident in the animals that died, and we have assumed that it was brought about by the dust itself. At 60 days the nodular lesions were still scanty, cellular, and discrete. At 90 days the reticulin network was largely replaced by collagen fibres, thick and compact (Fig. 1). (The fibrosis produced by a similar dose of flint is shown in Fig. 2.) The very high concentration of dust within the lesions is shown in Fig. 3. Animals which died at 101 and 105 days showed marked necrosis and acute inflammatory cell infiltration, in addition to the fibrotic nodules, but no microorganisms were demonstrated. Up to 330 days there was an increase in the number of nodules, but the maturity of their fibrosis was not increased, except in one animal, where they were fully collagenous although smaller







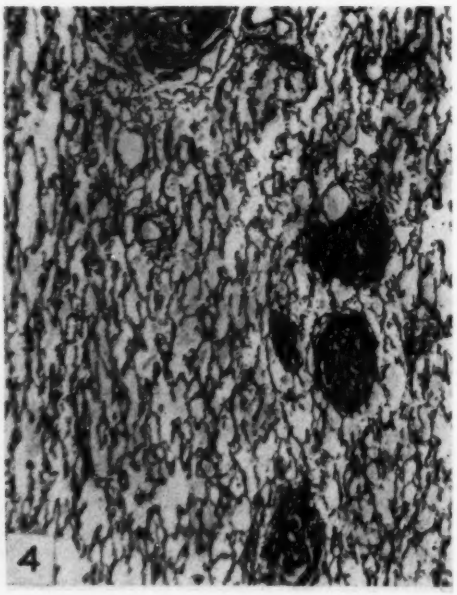


FIG. 1.—Compact, mainly collagenous nodules, in a rat lung, 90 days after 50 mg. calcium fluoride. Grade 3 fibrosis, Silver impregnation, × 76.

FIG. 2.—For comparison, rat lung 90 days after 50 mg. of flint. Grade 4 fibrosis.

FIG. 3.—Serial section to Fig. 1. Dark-ground illumination, showing dense, centrally deposited dust collections within the nodules. Micro-incinerated preparation, × 76.

FIG. 4.—Small, compact, wholly collagenous nodules, 330 days after 50 mg. calcium fluoride. Grade 4 fibrosis. Silver impregnation, × 76.

and fewer (Fig. 4). In the one animal remaining alive at 365 days they were likewise fewer and smaller, and they were less collagenous than in the 330-day-old animal, but in addition there were many thick bands of collagen in both lungs which were not aggregated together to form nodules.

The animals killed at 180, 300, and 365 days showed, in addition to the fibrotic nodular lesions, evidence of bronchiectasis with some bronchiectatic abscesses, septal thickening, destruction of lung tissue, and emphysema. The mode of death and histological assessment are given in Table 2.

The collagen analyses of these animals injected with 50 mg. of calcium fluoride were compared with the figures obtained by Stacy and King (1954) with a similar group of rats injected with 50 mg. quartz. The results are contained in Table 4. Up to 90 days

TABLE 4

COLLAGEN CONTENT OF LUNGS OF RATS INJECTED WITH CALCIUM FLUORIDE AND WITH QUARTZ*

Duration of Experiment (days)	Total Collagen in Both Lungs (mg.)		
	Calcium Fluoride in Rats	Quartz In Rats	Control Rats
30	18	12	16
34	20	—	—
40	13	—	18
42	14	—	—
60	31	39	17
81	34	—	16
90	33	42	—
91	27	—	—
105	28	—	21
120	—	94	21
150	36	141	26
180	68	90	21
210	36	115	24
240	—	400	24
270	—	146	—
275	39	—	—
300	37	247	—
330	34	151	—
365	32	158	—

*We are indebted to Dr. Brian Stacy and Dr. F. M. Englebrecht for these results.

there was not much difference, but thereafter the amount of collagen which formed in the calcium fluoride rats was very much less than that in the rats injected with quartz.

Discussion

In this experiment calcium fluoride had a marked toxic effect on the cells. Up to 120 days there was evidence of widespread aseptic necrosis of the lung tissue, associated with large amounts of dust lying free and within macrophage cells. Although there was certainly some fibrosis, the fibrotic nodular lesions were not nearly as prominent a feature as had been anticipated from the description of Policard and Collet (1953) of their results with the intraperitoneal injection of calcium fluoride. Injected intratracheally into the lungs, we found calcium fluoride very much less fibrogenic than quartz, although much more toxic to cells. Whether the minute traces of fluoride which may have remained on the HF-treated quartz, used in our previous experiment, had anything to do with the greater pathogenicity which it showed over the parent quartz from which it was prepared, remains in doubt. Recent experiments with quartz etched with HF and with NaOH showed similar enhanced fibrogenic activity and make this unlikely (Englebrecht, Yoganathan, King, and Nagelschmidt (1958). It might, however, be interesting to test the effect on the lungs of giving calcium fluoride and quartz simultaneously, in view of the very rapidly developing pneumoconiosis found by Luton and Champeix (1951) in workers in a fluoride mine who inhaled a mixed dust consisting of silica and calcium fluoride.

Summary

Calcium fluoride dust of 1μ mean diameter was injected into the lungs of rats. It had a severe toxic effect on the cells, especially during the early stages, leading to extensive necrosis. The fibrogenic capacity of calcium fluoride was much less marked than that of quartz, as seen histologically and as determined by chemical analysis of the collagen content of the lungs.

We are grateful to the Medical Research Council and to the National Coal Board for grants to defray the expenses of this investigation, and to Mr. B. S. C. Hollands for skilled technical assistance. The paper is published by permission of the Ministry of Fuel and Power.

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THE TISSUE REACTION IN THE LUNGS OF RATS AFTER THE INHALATION OF COAL DUST CONTAINING 2% OF QUARTZ

BY

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Belt and King (1945) found that pure coal dust, whether anthracite or bituminous, was of low pathogenicity, producing only minimal fibrosis; but there was some evidence to show that with increased siliceous matter in the coal the pathogenicity also increased. King, Harrison, and Ray (1949) found that when 5 and 10 mg. of quartz were mixed with 95 and 90 mg. of anthracite coal respectively and injected intratracheally into rats larger and more numerous nodules containing more reticulin resulted than were produced by the injections of clean coal (anthracite with very little ash). Ray, King, and Harrison (1951a) showed that when 2 mg. of quartz was given by intratracheal injection to rats there was no fibrotic reaction in the animals' lungs since it was removed to the hilar lymph nodes, where it did cause some fibrosis. Pure anthracite (100 mg.), when introduced into the lungs by the same route, also produced no pulmonary fibrosis, but when 2 mg. quartz was mixed with 98 mg. of pure anthracite coal and injected into the lungs, fibrotic nodules resulted. Ray *et al.* (1951b) realized the limitation of their experiment in that the intratracheal technique did not simulate dust inhalation. Hence, they suggested the repetition of the experiments by a dusting technique.

The present work was undertaken to find out whether a small amount of silica mixed with pure anthracite coal would lead to pulmonary fibrosis. Two dusting experiments were set up, the first with a light exposure to quartz alone and the second with a mixture of 2% quartz and 98% coal.

Methods and Materials

Quartz.—The powdered quartz was the same preparation as that used for the interlaboratory analytical trials (Nagelschmidt, 1956). All particles in this dust were under 10 μ (Table 1).

Anthracite Coal Dust.—The anthracite coal was obtained by Dr. B. M. Wright (Pneumoconiosis Research Unit, Cardiff) from a South Wales mine. Its ash content was 2·4%, mainly kaolin, with some haematite and no quartz. By chemical analysis about one-third of the ash was silica (from kaolin). It was ground in a " turbine grinder " (Wright, 1953) and then separated, using a Roller apparatus, into a fine fraction for dusting. All particles were under 14μ; 99% (by number) and 75% by mass were under 10μ (Table 1).

TABLE 1

PARTICLE SIZE DISTRIBUTION OF POWDERED QUARTZ AND ANTHRACITE COAL

Size (μ)	Quartz		Anthracite	
	No. (%)	Mass (%)	No. (%)	Mass (%)
0·23–0·45	49·1	0·4	8·7	—
0·45–0·64	23·3	3·3	10·7	0·1
0·64–0·9	11·1	4·4	14·6	0·2
0·9–1·3	8·9	9·7	15·2	0·5
1·3–1·8	4·5	14·1	12·3	1·2
1·8–2·6	2·2	19·1	16·3	4·6
2·6–3·6	0·6	14·9	12·4	9·7
3·6–5·1	0·35	24·3	4·7	10·6
5·1–7·2	0·05	9·8	3·0	19·1
7·2–10·2	—	—	1·6	28·7
10·2–14·4	—	—	0·5	25·3
Code No.	X1072			

Mixture of 98% Anthracite Coal and 2% Quartz.—An intimate mixture of 2% quartz (by weight) with 98% anthracite coal was prepared. Thorough mixing was ensured by grinding overnight in an electrically driven mortar. The airborne dust produced in the dusting cabinet from this mixture was sampled in London by the thermal precipitator and counted in Sheffield by the normal microscopic method used for evaluation of thermal precipitator samples, namely, an oil-immersion 2 mm. objective, a 17-fold eyepiece, and the sample mounted in air. A graticule with a $\sqrt{2}$ progression was used instead of the Patterson graticule. The mass distributions of coal and quartz were calculated from the counts (Cartwright, 1956). The distinction between coal and quartz was uncertain below 0·5 μ, but the resulting error is negligible for the mass proportions of coal and quartz. The counts showed all of the dust to be under 10 μ (Table 1a). In a representative sample total counts

TABLE 1a

COMPOSITION OF DUST CLOUD PRODUCED FROM MIXTURE OF 98% ANTHRACITE COAL WITH 2% QUARTZ

Size (μ)	Coal		Quartz	
	No. (%)	Mass (%)	No. (%)	Mass (%)
0·23–0·32	5·0	—	—	—
0·32–0·45	10·5	—	0·7	—
0·45–0·64	7·0	0·1	8·6	0·2
0·64–0·9	11·3	0·6	25·7	2·0
0·9 –1·3	19·6	3·2	20·0	4·3
1·3 –1·8	22·0	10·0	22·2	13·4
1·8 –2·6	16·2	20·5	15·7	27·0
2·6 –3·6	6·0	21·9	5·0	24·3
3·6 –5·1	1·6	16·5	2·1	28·8
5·1 –7·2	0·7	20·0	—	—
7·2 –10·2	0·1	7·2	—	—
MMD*	3·2		2·3	
σ*	1·7		1·7	

*MMD = mass median diameter: size at 50% mass on cumulative size distribution curve.

*σ = geometrical standard deviation: mean of ratios of diameters having 50% and 16·5% mass or having 83·5% and 50% mass.

of 612 coal particles and 140 quartz particles were made by counting quartz in 15 times the area used for the coal counts. The size distributions of coal and quartz were very similar (Table 1a). The calculated quartz percentage by mass was 2·1%. The mass median diameter (M.M.D) for coal was 3·2 μ, and for quartz the M.M.D. was 2·3 μ.

Dusting Cabinets.—The animals were placed in specially designed cabinets (King, Wright, Ray, and Harrison, 1950), in which the concentration of dust could be regulated (Wright, 1953). The overall dust concentrations (all particles under 10 μ) were determined by means of the thermal precipitator (Green and Watson, 1935), daily in the initial stages of the experiment and monthly as a check-up, and it was found that, having arranged conditions to produce a required dust cloud, the concentration remained reasonably constant over the course of the experiment. Size distributions of the airborne dusts are given in Table 1a for the mixed dust and in Table 1b for the quartz.

TABLE 1b

SIZE DISTRIBUTION OF DUST CLOUD PRODUCED FROM QUARTZ

Size (μ)	No. (%)	Mass (%)
0·23–0·32	23·2	0·2
0·32–0·45	24·0	0·5
0·45–0·64	9·3	0·5
0·64–0·9	10·5	1·6
0·9 –1·3	11·4	5·0
1·3 –1·8	11·4	13·9
1·8 –2·6	6·7	22·6
2·6 –3·6	2·7	26·4
3·6 –5·1	0·7	18·7
5·1 –7·2	0·1	10·6
Code No.	X1072	

Animals

The rats were of the black and white hooded variety of the Medical Research Council strain. They were males and their average weight was 150 g. Two groups of 30 animals were used in the quartz and the coal + 2% quartz experiments.

Dusting and Duration of the Experiments

The animals in the coal + quartz group were dusted on an average for 11 hours a day, five days a week, except for holidays and breakdowns. Because only half the rats could be accommodated at a time, and for convenience, this was done by exposing half the animals for five hours in the day and the other half for 17 hours overnight, changing over the animals once a week. After 330 days dusting was discontinued, and 14 animals kept for a further 110 days. Throughout the experiment the concentration of dust in the coal + quartz cabinet was maintained at 20,000 particles (0·2 to 10 μ) per millilitre of air. Based on the differential counts, this gave about 300 particles of quartz in the 20,000 particles of mixture per millilitre of air. The 20,000 particles for 11 hours corresponds to 20,000 × 11 = 220,000 " particle hours " of dusting per day, the 300 of quartz to 3,300 " particle hours ".

The rats in the quartz group were dusted for 90 minutes per day for five days per week with a dust cloud of 3,000 particles of quartz per millilitre of air, the lowest concentration which could be adjusted. The quartz dust exposure of 90 minutes (1·5 hour) with 3,000 particles per ml. was taken to correspond to 3,000 × 1·5 = 4,500 " particle hours " of dusting per day. Dusting was continued for 390 days, and 13 animals were kept for a further 110 days. The total " particle hours " of dusting, deaths, and killings are shown in Table 2.

TABLE 2

SURVIVAL TIMES AND " PARTICLE HOURS " OF DUSTING

Days of Survival	Quartz Alone (m. "particle hours")	Coal + 2% Quartz (m. "particle hours")
30	—	—
60	—	D*(1) 7·96
120	K(2) 0·30	K(2) 17·8
180	K(2) 0·45	K(2) 27·4
210	—	K(2) 32·2
240	K(2) 0·65	K(2) 37·3
270	K(2) 0·74	K(2) 41·7
280	—	D(1) 42·8
300	K(2) 0·85	K(2) 45·4
330	K(2) 0·94	K(2) 49·4
	D(1) 1·01	—
360	K(2) 1·02	—
390	K(2) 1·12	—
440	—	K(14) 49·4
500	K(13) 1·12	—

* K = killed and D = died. Numbers in brackets refer to numbers of rats killed or dead.

At the end of the dusting periods the surviving animals had been dusted as follows: quartz rats for 1 million particle hours; coal + 2% quartz rats for 49 million particle hours, which included 0·75 million quartz particle hours, *i.e.*, 49 million × 300/20,000.

Pathological Technique

Routine necropsies were carried out on all rats. The trachea was tied off, the thoracic cavity opened, and the lungs, with the tied-off portion of trachea, were removed and placed in 10% formol saline. Blocks were selected along the long axes of both the lungs at the level of the hilum to include the maximum representative area from each lung. The tracheo-bronchial glands were also fixed

in 10% formol saline. The fixation was completed in fresh fixative. The blocks of the lungs and tracheo-bronchial glands were embedded in paraffin separately and sections cut at 5 μ.

Chemical Analyses

The lungs and tracheo-bronchial lymph nodes of eight rats killed at 440 days from the coal + 2% quartz group and the lungs and lymph nodes of six rats killed at 500 days in the quartz group were dried overnight at 105° C., and each rat's lungs and lymph nodes were ground to a fine powder. The powder obtained from each pair of lungs and nodes in the coal + 2% quartz group was divided into two roughly equal parts; one was used for coal estimation (King and Gilchrist, 1945) and the other for chemical estimation of silica (King, Stacy, Holt, Yates, and Pickles, 1955). Suitable amounts of the powders obtained from the lungs and nodes of each of the rats in the quartz group were analysed for silica.

Results

Pathological Findings.—The rats dusted with quartz alone, even though they were dusted for a period of 500 days, did not show dust foci or macroscopic fibrosis either in the lungs or lymph nodes. The concentration of dust particles and the time of dusting (4,500 particle hours per day) were apparently insufficient to produce silicosis.

In the group inhaling the mixture of coal dust and quartz the rat which died at 60 days showed minute dust foci situated mainly on the dorsal aspect and free margins of the lungs. In the case of the rats killed at 120 days, dust accumulation in the lungs was characterized by the presence of dust foci, larger than those seen at 60 days, situated on both the pleural and cut surfaces of the lungs and separated by unpigmented lung tissue. During the remaining period of the experiment the dust foci were seen gradually to increase in size, but their distribution appeared to be more or less constant. The rats killed at 330 and 440 days showed dust foc,i about 1 to 2 mm. in diameter.

The most marked macroscopic changes were to be seen in the tracheo-bronchial lymph nodes. At 60 days the nodes were slightly enlarged and a few discrete groups of accumulated coal dust were seen in them. At 120 days they were still larger and covered with heavy deposits of coal which obscured the normal lymphoid tissue. At 330 days the nodes were about three times their normal size and at 440 days they were completely filled with coal dust.

Microscopic Appearances.—Histologically the lungs and lymph nodes of the rats dusted with quartz alone did not show any evidence of fibrosis. A few doubly refractile particles could be seen in tiny subpleural drifts, and in macrophages scattered throughout the lung, at all stages of dusting. In the lymph nodes, they were collected together in very small foci, in which only a few reticulin fibres were seen.

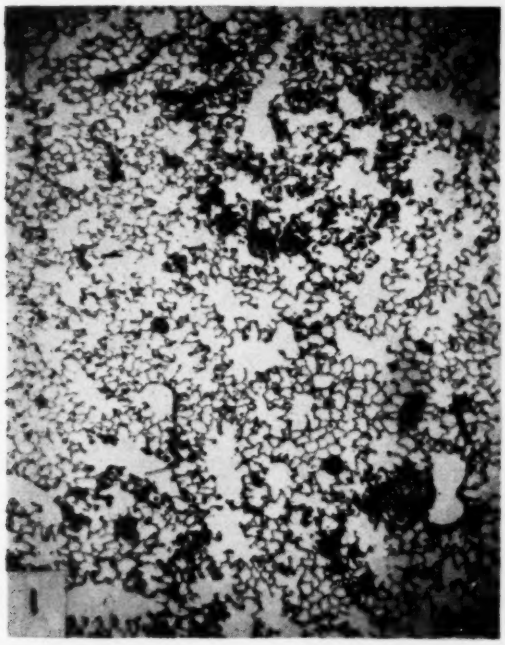
The lungs of the rat dusted with coal + 2% quartz for 60 days showed that most of the dust was engulfed by macrophages which were scattered throughout the lungs. A very few free coal particles were also seen. At 120 days the dust-laden macrophages were seen to lie singly or grouped into small foci (Fig. 1). The outlines of the macrophages in some places were obscured by the compact masses of coal, and many of the alveolar walls appeared thickened due to cellular swelling and proliferation. From this period onwards up to 300 days the dust collections became more compact, and at these sites the alveolar septa were obliterated. At 330 days there were definite circumscribed foci of coal dust throughout the lungs (Fig. 3). They gradually increased in size, and at 440 days were fairly large, but there was no evidence of fibrosis.

In sections of the lymph nodes at 60 days macrophages were seen, laden with coal dust, and at 120 days were seen to form nodular masses situated mostly at the periphery and in between the lymphoid follicles of the lymph nodes (Fig. 2). As the hours of dust exposure were increased, more and more dust accumulated in the lymph nodes, and at 440 days they were loaded with irregular clumps of coal dust (Fig. 4).

Gordon and Sweets' (1936) silver impregnation of the lungs showed no increase of reticulin in the lungs of any of the animals dusted with coal + 2% quartz. The lymph nodes of the rats in this group showed the presence of a few thin reticulin fibres around the dust foci at 330 days, and more and thicker reticulin fibres were seen amidst the dust foci in the lymph nodes at 440 days.

Silica and Coal Content of Lungs.—In six rats dusted with quartz and killed at 500 days the total silica present varied from 0·24 mg. to 0·35 mg., mean value 0·31 mg. (Table 3). This was a much lower content than had been expected.

In eight rats dusted with 98% coal and 2% quartz and killed at 440 days the total amount of coal present varied from 23·5 mg. to 72·5 mg., mean value 42·9 mg. The total silica present varied from 1 mg. to 3·28 mg., mean value 2·02 mg. Silica derived from the kaolin in the coal ranged from 0·19 mg. to 0·58 mg., mean 0·34 mg. After deducting these values from the total silicas, the values of silica from quartz ranged from 0·79 mg. to 2·76 mg., mean value 1·68 mg. The mean quartz percentage of the lung dust was 3·7, suggesting some preferential inhalation or retention of quartz.



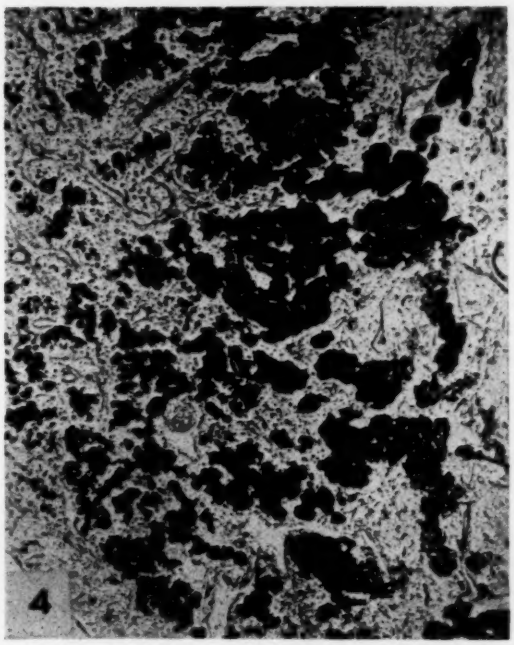


FIG. 1.—Rat lung, dusted 120 days (17·8 million " particle hours ") with a mixture of anthracite dust 98% and quartz 2%. Macrophages laden with coal dust in alveoli and collections of dust in small compact masses. Haematoxylin and eosin, × 50.

FIG. 2.—Tracheo-bronchial lymph node from same rat as in Fig. 1. Dust seen in periphery and between germinal centres; lymph sinuses patent; no fibrosis. Haematoxylin and eosin, × 50.

FIG. 3.—Rat lung, dusted 330 days (49·4 million " particle hours ") with a mixture of anthracite dust 98% and quartz 2% and killed 110 days after the cessation of dusting. Dust collected in definite foci. Very few reticulin fibres. Haematoxylin and eosin, × 50.

FIG. 4.—Tracheo-bronchial lymph node from same rat as in Fig. 3. Dust present in large masses which are tending to fuse together. Very few reticulin fibres. Haematoxylin and eosin, × 50.

TABLE 3

ANALYSES OF LUNGS AND LYMPH NODES FROM RATS DUSTED WITH QUARTZ AND WITH MIXTURE OF ANTHRACITE COAL (98%) AND QUARTZ (2%)

Dry Weight of Lungs and Lymph Nodes (g.)	Coal in Lungs and Lymph Nodes (%)	SiO_2 in Lungs and Lymph Nodes (%)	Total Coal Present (mg.)	Total SiO_2 Present (mg.)	SiO_2 from Siliceous Matter *from Coal (mg.)	Silica from Quartz† (mg.)
Dusted with Coal + 2% Quartz (killed at 440 days)						
1·086	3·75	0·16	40·7	1·73	0·33	1·40
1·161	5·61	0·28	65·2	3·28	0·52	2·76
0·754	3·12	0·21	23·5	1·57	0·19	1·38
1·014	2·86	0·22	29·0	2·22	0·23	1·99
0·811	3·65	0·15	29·6	1·23	0·24	0·99
0·727	7·73	0·32	56·2	2·30	0·45	1·85
1·029	7·05	0·27	72·5	2·80	0·58	2·22
0·816	3·25	0·12	26·5	1·00	0·21	0·79
Mean Values 0·927	4·62	0·22	42·9	2·02	0·34	1·68
Dusted with Quartz (killed at 500 days)						
0·711	—	0·04	—	0·28	—	—
0·709	—	0·05	—	0·35	—	—
0·457	—	0·07	—	0·32	—	—
0·838	—	0·04	—	0·34	—	—
0·779	—	0·03	—	0·24	—	—
0·396	—	0·08	—	0·32	—	—
Mean Values 0·648	—	0·06	—	0·31	—	—

* Calculated from the silica content of anthracite coal (2·4% × 1/3 = 0·8%).
† By difference.

Discussion

The inhalation of anthracite coal dust with small amounts (2%) of quartz over prolonged periods led to the development of dust foci, scattered throughout the lungs, without any fibrosis. The accumulations of dust were in the alveoli, respiratory bronchioles, and alveolar ducts. These findings are similar to those of Heppleston (1954) in the lungs of rabbits inhaling coal dust underground; but, unlike Heppleston's rabbits, our rats did not develop any marked focal emphysema. Gross (1931) noted thickening of the alveolar walls without any fibroblastic changes in the lungs of rabbits dusted with coal dust, which closely resembles the findings of these experiments. Badham (1940) concluded that prolonged dusting of rabbits and guinea-pigs with coal dust does not cause pulmonary fibrosis.

Heppleston (1954) found that relatively little dust entered the lymphatic system of rabbits exposed to coal dust; but in our experiment the tracheobronchial lymph nodes of the rats dusted with anthracite coal dust and quartz showed nodular masses of dust when the dust-laden macrophages were still lying singly or grouped in small foci in the lungs. At all times there appeared to be a much higher concentration of dust in the lymph nodes than in the lungs. These findings support the views of Willis (1921) and Gardner (1940), who were of the opinion that it is only after the hilar glands have become choked with dust that a parenchymal accumulation begins, gradually extending from the hilar region towards the periphery of the lung.

Because Ray *et al.* (1951a, b) had found some fibrosis to result when 2 mg. of quartz with 98 mg. of coal was intratracheally injected into rats, we were surprised at the comparative absence of pulmonary fibrosis in the present experiments. In the intratracheal injection method the whole of the dust is introduced in one dose and acts in the lung from the beginning; about half of it is permanently retained (Nagelschmidt, Nelson, King, Attygalle, and Yoganathan, 1957). After 440 days' dusting in the present experiment, only 1·68 mg. (on the average) of quartz was found in the lungs and lymph nodes. There is no evidence of the rate at which the quartz accumulated, but during most of the experimental periods there must have been much less than these amounts present. We had not, in fact, achieved in these dusting experiments sufficiently high concentrations of quartz in the lungs, nor had the amounts retained been there long enough to produce more than a mild reticulinosis in the lymph nodes, despite the simultaneous presence of considerable amounts (30 to 70 mg.) of coal.

Rats dusted with a dust cloud of 3,000 particles of quartz per millilitre of air for 1·5 hours per day over a period of about 400 days (1·12 million "particle hours'" dusting) did not show any evidence of fibrosis in the lungs or lymph nodes.

The chemical analyses of the lungs and lymph nodes of rats dusted with the mixture of coal and 2% quartz showed variable amounts of coal and silica. The mean silica from quartz value (1·68 mg. per rat) was five times higher than the silica found in the lungs and lymph nodes of the rats dusted with quartz alone (0·31 mg. per rat), although the mixed dust group had had a lower total exposure to quartz, *i.e.*, 0·75 as against 1·1 million "particle hours". This finding suggests that small amounts of dust are got rid of without causing any damage

to the lungs or lymph nodes. When they contain large amounts of coal, the lungs may not be able so readily to rid themselves of small amounts of quartz.

It is interesting to compare the dosage and retention of dust observed with recent data given by Wright (1957), who used a gravimetric thermal precipitator and found, after 18 months of dusting with coal (100 hours per week, experiment 3A), an average value of 97 mg. per rat which corresponded to 22% retention of the dust inhaled.

A rough calculation of the total weight below 7 μ given to our mixed dust group, using the same rat minute value of 100 ml. as taken by Wright, gives a total intake of 1,000 mg. or a recovery of only 4·4%. But as our cloud must have been about six times as concentrated as that used by Wright there may have been more aggregation and consequently less uptake into the lungs. Furthermore, Wright's rats were killed and analysed immediately after the end of the dust exposure, whereas ours survived without dusting for another 110 days and may have eliminated some dust. It would be desirable, in future experiments, to measure the dust dosage simultaneously by gravimetric and counting techniques in order to establish accurately the pattern of the relationship between dust exposure and retention, in lungs and lymph nodes, of inert and fibrogenic dusts and their mixtures.

Summary

Rats were dusted, over a period of 500 days, with (1) a low concentration of quartz, and (2) a high concentration of anthracite coal dust containing 2% of added quartz.

There was no fibrosis produced in the lungs or lymph nodes of animals dusted with the low concentration of quartz alone. The amounts of silica found by analysis in these rats were much less than those in the mixture of anthracite and 2% quartz rats, despite the " quartz particle hours " of dusting being roughly similar.

In the rats dusted with the mixture of 98% anthracite and 2% quartz, discrete dust foci developed in the lungs and lymph nodes, without showing any evidence of fibrosis in the lungs and only a little in the lymph nodes.

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TABLE 3

ANALYSES OF LUNGS AND LYMPH NODES FROM RATS DUSTED WITH QUARTZ AND WITH MIXTURE OF ANTHRACITE COAL (98%) AND QUARTZ (2%)

Dry Weight of Lungs and Lymph Nodes (g.)	Coal in Lungs and Lymph Nodes (%)	SiO_2 in Lungs and Lymph Nodes (%)	Total Coal Present (mg.)	Total SiO_2 Present (mg.)	SiO_2 from Siliceous Matter *from Coal (mg.)	Silica from Quartz† (mg.)
Dusted with Coal + 2% Quartz (killed at 440 days)						
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PNEUMOCONIOSIS OF COAL-MINERS IN THREE NORTHUMBRIAN COLLIERIES

BY

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Radiological pneumoconiosis is common amongst coal-miners in County Durham, and in four collieries about 22% of men at work above and below ground had fairly well-marked lung changes of category 2 or more (McCallum and Browne, 1955).

There are no reliable prevalence data for pneumoconiosis of coal-miners in the adjacent coalfield of Northumberland, but its mines are thought to produce little pneumoconiosis compared with those of Durham and the rest of the country. In the Outpatient Clinic of the Nuffield Department of Industrial Health relatively few men with pneumoconiosis of coal-miners are seen from Northumberland, the majority being Durham miners. Practically the only information available is the number of men certified under the various pneumoconiosis compensation acts since 1933 when faceworkers in mines were first included (Table 1). During the 10 years following 1933 Hume (personal communication) as a medical referee saw 100 men from Durham pits and only 15 from Northumberland. The figures for South Wales for the period 1933 to mid-1948 are taken from Hugh-Jones and Fletcher (1951).

Between 1943 and 1948, the worst three pits in Northumberland had only nine, nine, and four men certified respectively (Hume), and the records of the National Union of Mineworkers (Northumberland) show 41 men certified and six deaths from Northumberland compared with the Durham area of the N.U.M. which had 322 men certified and 46 deaths in the same period. There are about two and a half times as many men employed at coal-mines in Durham compared with Northumberland but the certification rate per man in Durham is two to three times greater. Data published by the Ministry of Fuel and Power (1950-1954) of men certified by the Pneumoconiosis Medical Panel show on the average for 1951-1953 about 1·6 per 1,000 in Northumberland and 4 per 1,000 in Durham. In these three years, most Northumbrian miners certified by pneumoconiosis boards were over 45 years of age, only two men being less than 35 years of age, and the majority of assessments for disability were under 40% loss of faculty.

Until 1942 the number of men certified was not more than three a year from Northumberland and 21 a year from Durham, but since 1948 the number of men certified by the Pneumoconiosis Panel has increased sharply, following the new National Insurance (Industrial Injuries) Act.

TABLE 1

NUMBER OF MEN CERTIFIED BY SILICOSIS OR PNEUMOCONIOSIS BOARDS IN DURHAM AND NORTHUMBERLAND WITH COMPARATIVE DATA FOR SOUTH WESTERN DIVISION

Period	Northumberland (Approximately 40,000 Employed)		Durham (Approximately 100,000 Employed)		South Western Division (Approximately 107,000 Employed)	
	No. of Men	Per 1,000 Employed	No. of Men	Per 1,000 Employed	No. of Men	Per 1,000 Employed
1933–42	15	0	100	1	3,540	33
30.6.43 to 5.7.48	41*	1	322†	3	15,080	140
5.7.48 to 25.3.50	36	1	338	3	5,638	53
27.3.50 to 30.12.50	18	0	176	2	1,511	14
1951	70	2	395	4	1,221	11
1952	31	1	390	4	1,036	10
1953	89	2	435	4	1,061	10
1954	94	2	616	6	921	9

* Plus 6 deaths

† Plus 46 deaths

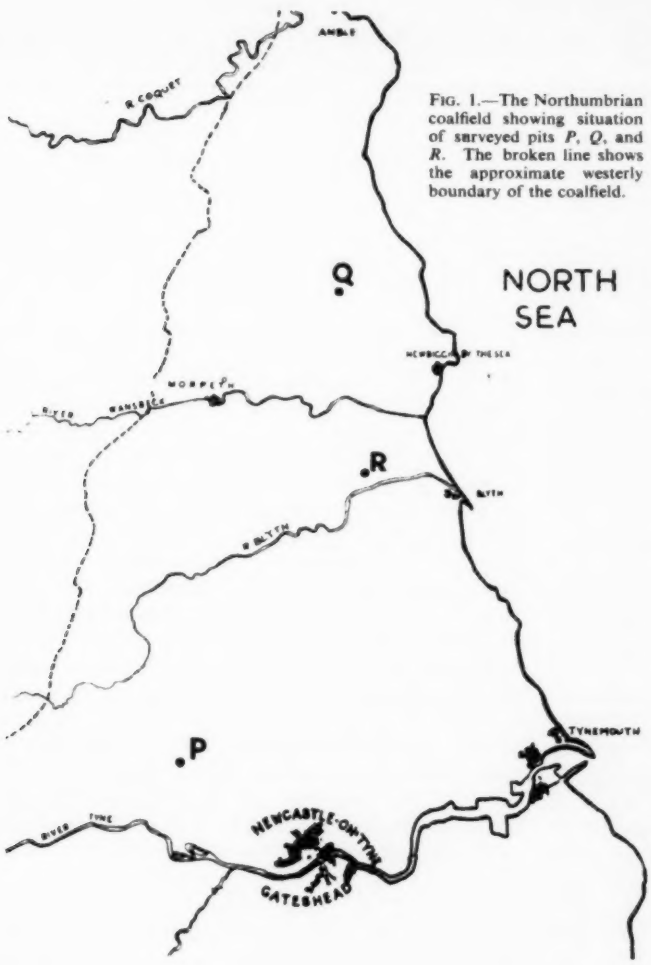

FIG. 1.—The Northumbrian coalfield showing situation of surveyed pits *P*, *Q*, and *R*. The broken line shows the approximate westerly boundary of the coalfield.

Present Survey

A survey comparable to that already made in Durham was carried out in three Northumbrian pits in 1953/54 to determine the prevalence of radiological abnormality. Only large (12 in. × 15 in.) films were used and these were taken by a mobile mass radiography unit provided by the Newcastle Regional Hospital Board.

It must be emphasized that any estimate of the prevalence of pneumoconiosis relates to dusty conditions existing during the 30-40 years preceding the investigation and that no precise information about the past environment exists nor are any dust counts available even from the period immediately before the survey.

Choice of Pits.—Three pits (*P*, *Q*, and *R*) were chosen on a basis of geography, size, and type. They were situated in the upper, middle, and lower parts of the coalfield which is roughly wedge-shaped with its apex pointing north (Fig. 1). The largest pit had 1,254 men and the smallest 1,072 and all three were considered, in general, typical Northumbrian pits in working methods and coal seams. They are now fully mechanized and coal is won entirely mechanically, either by arc-wall cutting as in Pit *R* or by long-wall cutting as in *P* and *Q*. For the five-year period before 1948 the number of men certified (total and partial) from Pits *P*, *Q*, and *R* was one, three, and two respectively, and from 1949 to the end of 1952, four, four, and three respectively.

Organization of Survey and Radiology.—The organization of the survey, the method of reading radiographs, and the follow-up of those who did not attend were similar to those described in a survey of four Durham collieries (McCallum and Browne, 1955). Radiographs were categorized according to the proposed International Classification of Pneumoconiosis (Cochrane, Davies, and Fletcher, 1951; International Labour Office, 1953) by three viewers working separately and the median of their readings was taken as the final category. Where disagreement was marked additional readings were made. The length of time spent by the radiography unit at each colliery during this survey was about two full weeks.

Prevalence

Eighty-five per cent of 3,400 men at work above and below ground had a chest radiograph at these three collieries (Table 2). About a quarter (24·8%)

TABLE 2
NUMBER* AND PERCENTAGE OF MEN RADIOGRAPHED

Colliery	Total Number of Men from Pay Record	Men Radiographed		Men not Radiographed	
		No.	%	No.	%
P	1,072	930	86·8	142	13·2
Q	1,254	1,087	86·7	167	13·3
R	1,074	881	82·0	193	18·0
Total ..	3,400	2,898	85·2	502	14·8

*The total number of men employed at the colliery was obtained from the pay records at the time of the survey.

TABLE 3

PERCENTAGE OF EXAMINED MEN WITH PNEUMOCONIOSIS IN EACH COLLIERY BY CATEGORIES

Category	Colliery							
	P		*Q*		*R*		Total	
	No.	%	No.	%	No.	%	No.	%
1	113	12·2	177	16·3	107	12·1	397	13·7
2	87	9·4	82	7·5	72	8·2	241	8·3
3	15	1·6	26	2·4	26	3·0	67	2·3
P.M.F.	5	0·5	5	0·5	3	0·3	13	0·4
Total	220	23·7	290	26·7	208	23·6	718	24·8

of the 2,898 men radiographed have pneumoconiosis of Category 1 or more (Table 3) and 11% pneumoconiosis of Category 2 or more. There are no marked differences between the proportion of each category in the three pits with the exception of *Q*, which appears to have an excess in Category 1, but this difference is not statistically significant and could have arisen by chance.

When the ages of the men radiographed are considered (Table 4), *P* has relatively more men over 46 years of age; *Q* has more men in the 26-35 years and 26-45 years groups; *R* has 48·5% of the 15-25 years group and a smaller proportion than the other two pits in the three older groups.

TABLE 4

NUMBER AND PERCENTAGE OF MEN RADIOGRAPHED IN EACH COLLIERY BY AGE

Age	Colliery						Total	
	P		*Q*		*R*			
	No.	%	No.	%	No.	%	No.	%
15–25	99	22·6	127	28·9	213	48·5	439	100·0
26–35	161	24·5	297	45·1	200	30·4	658	100·0
36–45	209	32·6	261	40·7	172	26·8	642	100·1
46–55	242	37·2	240	36·9	168	25·8	650	99·9
56+	219	43·0	162	31·8	128	25·1	509	99·9
Total	930	32·1	1,087	37·5	881	30·4	2,898	100·0

When the amount of pneumoconiosis is related to the age of the men in 10-year groups (Table 5), there are only 60 men out of 1,097 under 35 years who have any pneumoconiosis at all and most of the men with Category 3 pneumoconiosis are over 45 years of age. In each category of pneumoconiosis the proportion of men affected increased systematically with advancing age, and there is no tendency to level out after a particular age. The same trend is seen in each colliery separately (Table 6), but colliery *Q* has four to five times the proportion of men with pneumoconiosis in the 26-35 years age group compared with *P* and *R*. There is a higher proportion of faceworkers in this age group in *Q* and therefore probably more men who worked in very dusty conditions but their pneumoconiosis is all very slight.

TABLE 6

MEN WITH PNEUMOCONIOSIS (CATEGORY 1 AND ABOVE) IN EACH COLLIERY BY AGE AS A PERCENTAGE OF ALL MEN RADIOGRAPHED IN EACH AGE GROUP

Age	Colliery						Total	
	P		*Q*		*R*			
	No.	%	No.	%	No.	%	No.	%
15–25	—	—	3	2·4	1	0·5	4	0·9
26–35	5	3·1	44	14·8	7	3·5	56	8·5
36–45	33	15·8	64	24·5	48	27·9	145	22·6
46–55	82	33·9	98	40·8	79	47·0	259	39·8
56+	100	45·7	81	50·0	73	57·0	254	49·9

The 13 men with progressive massive fibrosis (Table 5) were all placed in Category *A*, the earliest degree of P.M.F. and none had advanced disease. The radiograph showed a background of Category 2 in seven men and Category 3 in six men. Eight members of the office staff at the three pits were radiographed and all were placed in Category 0.

Faceworkers

As in the Durham survey the term " faceworker " is used for men who have at any time worked for six months or more as hewer, coal-cutter, filler, stoneman, deputy, shotfirer, or in a combination of these, such as " composite work " (coal hewing and stonework).

The occupational histories of the faceworkers gave the proportion of time that they spent in each

TABLE 5

NUMBER AND PERCENTAGE OF MEN IN EACH RADIOLOGICAL CATEGORY BY AGE

Age	Radiological Category										Total	% in Category 1 and Over	% in Category 2 and Over
	0		1		2		3		P.M.F.				
	No.	%	No.	%	No.	%	No.	%	No.	%			
15–25	435	99·1	4	0·9	—	—	—	—	—	—	439	0·9	—
26–35	602	91·5	50	7·6	5	0·8	—	—	1	0·2	658	8·5	0·9
36–45	497	77·4	97	15·1	44	6·9	4	0·6	—	—	642	22·6	7·5
46–55	391	60·2	125	19·2	101	15·5	30	4·6	3	0·5	650	39·8	20·6
56+	255	50·1	121	23·8	91	17·9	33	6·5	9	1·8	509	49·9	26·1
	2,180	75·2	397	13·7	241	8·3	67	2·3	13	0·4	2,898	24·8	11·1

TABLE 7

PROPORTION OF TIME SPENT IN VARIOUS TYPES OF FACEWORK AT EACH COLLIERY DERIVED FROM SUBJECTS' OCCUPATIONAL HISTORIES

Type of Work	Percentage Years Spent at Coalface			
	Colliery			Total
	P	*Q*	*R*	
Hand hewing	24	1	2	10
Pneumatic hewing	1	—	—	—
Hewing, unspecified	5	7	12	8
Composite work	5	15	2	9
Coal cutting	8	16	9	11
Stonework	22	16	32	22
Filling	25	35	32	30
Deputy	10	10	11	10
Total	100	100	100	100

colliery at various jobs (Table 7). Hand hewing had been used extensively in the past in Pit *P* compared with *Q* and *R* and there was practically no pneumatic hewing. Some of the unspecified hewing and composite work may have been by pneumatic pick, although most of it was probably hand work. The large amount of time at filling (30%) and stonework (22%) relative to coal cutting is consistent with the general use of mechanical cutters. In Pit *Q* rather more time was spent on composite work than in the other collieries, and deputy work took the same proportion of time in all three.

About 85% of the faceworkers' years at the face were spent at the colliery in which they were radiographed (Table 8).

Fifty-six per cent. of the men began facework between the ages of 20 and 24 years but 18% were between 14 and 19 years of age when they started. After 25 years of age the numbers starting facework fall off but a few men go on to facework for the first time up to the age of 45.

TABLE 8

PROPORTION OF FACEWORKERS' YEARS AT FACE SPENT AT THEIR PRESENT COLLIERY

Category	*P* (%)	*Q* (%)	*R* (%)
0	88	83	84
1	81	87	88
2	82	81	81
3	69	80	93
P.M.F.	79	100	100
Average ..	85	84	85

Radiographic Category by Years at Face and Age

The effect of time at facework on radiological category is shown in Table 9 and Fig. 2. There is an increase in the proportion of men in each category with rise in years at the face, except in the P.M.F. group which comprises only 13 men. After more than 10 years' facework there is a marked rise in the percentage of men in each category, and there are none in category P.M.F. with less than 10 years at facework. Individual collieries (Table 10) show much the same trend but *Q* has more pneumoconiosis in each 10-year period than *P*, and *R* has more still after more than 10 years at facework.

TABLE 10

PERCENTAGE OF PNEUMOCONIOSIS (CATEGORY 1 AND ABOVE) BY COLLIERIES

Years at Face	Colliery			Total
	P	*Q*	*R*	
0	5	10	5	6·6
1–10	5	13	12	10·5
11–20	30	37	46	36·9
21–30	45	52	55	50·1
31+	58	63	81	65·0

When men with pneumoconiosis of Category 2 or more are compared by age and number of years at facework (Table 11), all except six are over 35 years of age and there are only eight men who have done no facework. Ninety-six of these men who are aged 56 years and over have spent more than 30 years at facework. Numbers in each group are rather small but in the two older age groups (46-55 years and 56+) years at facework is more important in increasing category than is age.

Withdrawals

Withdrawals of men from facework to other work at the same colliery increase with age rather than

TABLE 9

NUMBER AND PERCENTAGE OF MEN IN EACH RADIOLOGICAL CATEGORY BY YEARS AT FACEWORK

No. of Years at Face	Radiological Category										Total	% in Category 1 and Over	% in Category 2 and Over
	0		1		2		3		P.M.F.				
	No.	%	No.	%	No.	%	No.	%	No.	%			
0	999	93·4	63	5·9	7	0·7	1	0·1	—	—	1,070	6·6	0·7
1–10	589	89·5	53	8·1	15	2·3	1	0·2	—	—	658	10·5	2·4
11–20	274	63·1	96	22·1	57	13·1	4	0·9	3	0·7	434	36·9	14·7
21–30	203	49·9	92	22·6	80	19·7	30	7·4	2	0·5	407	50·1	27·5
31+	115	35·0	93	28·3	82	24·9	31	9·4	8	2·4	329	65·0	36·8
	2,180	—	397	—	241	—	67	—	13	—	2,898	—	—

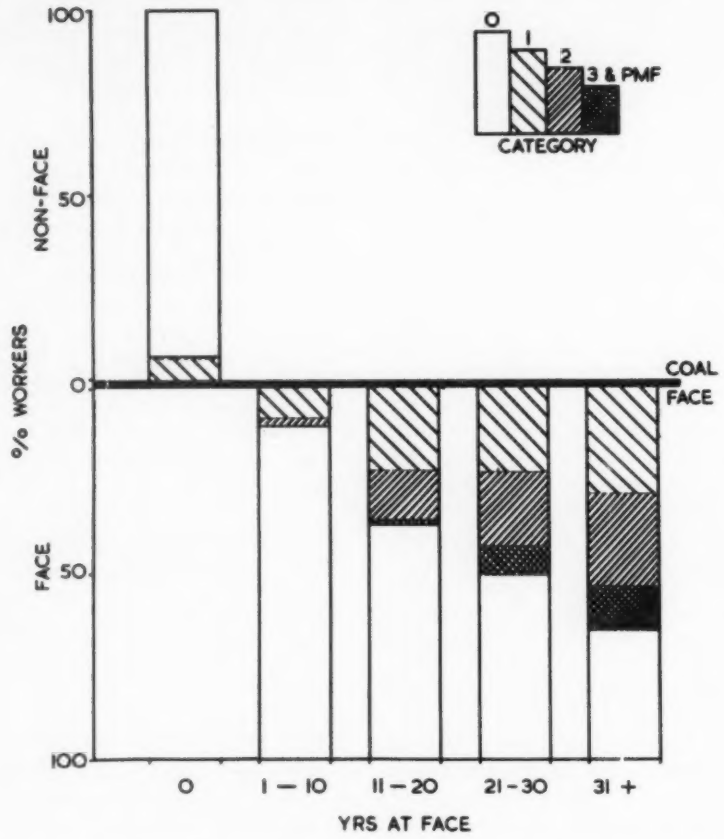

FIG. 2.—The proportion of men with pneumoconiosis related to years at facework.

with radiological category (Table 12), except in the small number of men with P.M.F. Six men with P.M.F. over 56 years of age are still at facework, out of a total of only nine men in this group.

Non-faceworkers with Pneumoconiosis.—Many of these men had done a variety of surface work but there was usually a predominant job which lasted for seven years or more. Several men did the same work for many years, *e.g.*, a screener for 37 years or a blacksmith for 53 years. There were 13 screeners and eight blacksmiths with pneumoconiosis, mainly Category 1, and six bricklayers with Category 1 changes who worked underground for varying periods. Various other occupations above and below ground, such as datal worker, electricians, and pit-heap workers, are also represented, but all in Category 1.

TABLE 11

MEN WITH PNEUMOCONIOSIS OF CATEGORY 2 OR MORE BY AGE AND YEARS OF FACEWORK

Age	Years at the Face										Average Total	
	0		1–10		11–20		21–30		31 and Over			
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
15–25	—	—	—	—	—	—	—	—	—	—	—	—
26–35	—	—	3	0·8	3	4·5	—	—	—	—	6	0·9
36–45	2	1·0	4	2·6	22	11·1	20	21·1	—	—	48	7·5
46–55	1	0·7	5	7·2	28	23·9	75	30·9	25	32·1	134	22·1
56+	5	4·6	4	12·9	11	21·6	17	24·6	96	38·4	133	26·1
Total ..	8	0·7	16	2·4	64	14·7	112	27·5	121	36·8	321	11·1

TABLE 12

TOTAL FACEWORKERS OR FORMER FACEWORKERS BY AGE AND CATEGORY SHOWING NUMBER AND PERCENTAGE WITHDRAWN FROM FACEWORK FOR AT LEAST SIX MONTHS AT TIME OF SURVEY BUT STILL EMPLOYED AT THE COLLIERY*

Age in Years		Radiological Category										Totals	
		0		1		2		3		P.M.F.			
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
26–35	Faceworkers	376	—	40	—	5	—	—	—	1	—	422	—
	Withdrawn	20	5·3	3	7·5	—	—	—	—	—	—	23	5·5
36–45	Faceworkers	320	—	80	—	42	—	4	—	—	—	446	—
	Withdrawn	38	11·9	15	18·8	3	7·1	—	—	—	—	56	12·6
46–55	Faceworkers	267	—	107	—	100	—	30	—	3	—	507	—
	Withdrawn	83	31·1	28	26·2	36	36·0	7	23·3	3	100·0	157	31·0
56+	Faceworkers	167	—	106	—	87	—	32	—	9	—	401	—
	Withdrawn	80	47·9	36	34·0	40	46·0	11	34·4	3	33·3	170	42·4

*No information is available concerning men who have left the pit altogether.

Pulmonary Tuberculosis

Thirty-five men were referred to chest clinics for further observation (Table 13). Ten men from colliery *P*, seven from *Q*, and three from *R* had pulmonary tuberculosis and the remaining 15 men had pulmonary or cardiac conditions requiring investigation. Of the 20 men with pulmonary tuberculosis, seven were thought to have active disease on purely radiological grounds, and the remainder to require further observation. Three men, all at colliery *P*, had sputa positive for tubercle bacilli, 11 had negative sputa, and six men failed to attend for investigation.

TABLE 13

MEN REFERRED TO CHEST CLINICS FROM THE SURVEY

Colliery	Pulmonary Tuberculosis					Other Chest Conditions
	Radiologically		Sputum		Did not Attend	
	Active	Inactive	Positive	Negative		
P	4	6	3	7	0	3
Q	2	5	0	3	4	10
R	1	2	0	1	2	2
Total	7	13	3	11	6	15

The proportion of men with radiological signs of past pulmonary tuberculosis (excluding primary complex) follows the same order, being highest in colliery *P* and lowest in *R* (Table 14).

TABLE 14

MEN SHOWING RADIOLOGICAL EVIDENCE OF PAST PULMONARY TUBERCULOSIS BY AGE AND COLLIERY (ALL CATEGORIES)

Age in Years	Colliery					
	P		*Q*		*R*	
	No.	%	No.	%	No.	%
15–25	3	3·0	—	—	1	0·5
26–35	8	5·0	5	1·7	4	2·0
36–45	6	2·9	4	1·5	2	1·2
46–55	8	3·3	14	5·8	5	3·0
56+	15	6·8	9	5·6	5	3·9
	40	4·3	32	2·9	17	1·9
Standardized rates		3·9	—	3·0	—	2·1

Non-attenders

Five-hundred-and-two men (14·8%) did not attend for radiography but 348 of them were interviewed personally (Table 15). Sufficient information was gained from visiting these men to place them in faceworker or "non-faceworker" groups, and 202 (5·9%) of the latter failed to attend compared with 146 (4·3%) faceworkers. It was unfortunately not always possible to obtain the age of non-attenders who were not interviewed personally, but for those whose age was known the number in age group 15-25 years was relatively large, possibly because some men who were on the colliery books were in fact doing national service. In men aged 26 and over those not attending had a similar age structure to those radiographed.

TABLE 15

MEN NOT RADIOGRAPHED BUT VISITED BY A SOCIAL WORKER

Colliery	Men Visited		Men not Interviewed Personally	Total
	Non-faceworkers	Faceworkers		
P	60	37	45*	142
Q	59	68	40	167
R	83	41	69†	193
Total..	202	146	154	502
% of total number of men on payroll at all collieries	5·9	4·3	4·5	14·8

*22 of these men were under 21 years of age.
†36 of these men were under 21 years of age.

Stonework and Radiological Category

An attempt was made to determine whether working in stone for long periods has a greater tendency to produce radiological changes than similar periods

of work in coal only, or in coal and stone. No difference in the prevalence of pneumoconiosis was found for men who have worked predominantly in stone and were therefore presumably exposed to more silica than coal-getters or composite workers (mixed coal and stoneman). As men become older the number who continue to work in stone exclusively decreases, while coal-getters tend to continue as such and it is possible that complete withdrawal from the industry affects stoneworkers more because of advanced pneumoconiosis (P.M.F.) or silicosis but there is no information about men who have left these pits.

Discussion

The value of prevalence studies of coal-miners' pneumoconiosis has recently been discussed by Cochrane, Davies, Chapman, and Rae (1956) who point out that the prevalence rate measures the size of the problem, and is a necessary first step in the measurement of attack and progression rates, although similar prevalence rates may represent very different attack and fatality rates. The present investigation was made to determine how common certain radiological abnormalities were in Northumbrian miners compared with Durham miners and miners elsewhere in Britain. In dealing with pneumoconiosis as a clinical problem in this area such prevalence studies have considerable practical value in bringing the problem into perspective and in allaying fears among the miners. The overall prevalence of pneumoconiosis of Category 2 or more in the Durham collieries (1950-51) was 22% compared with 11% in the Northumbrian collieries (1953-54), but it may be misleading to compare these figures if the age structure of the group of men studied is not taken into account. In fact the age distribution of men radiographed in Durham was generally similar to that of the Northumbrian miners except in the 56-plus group in which there were rather more men in Northumberland (17%) than in Durham (13%). This may be a result of less pneumoconoisis and a very small amount of disabling P.M.F. in Northumberland. These figures suggest that if the age structures of working miners in the two counties had been identical the difference in amount of pneumoconiosis would have been accentuated.

In north-east England the natural progression of a miner's work is from a short period at bank as a youth through datal work underground to facework, as a hewer, cutter, filler, or stoneworker. In middle age or later a miner returns to datal work or to bank as age or infirmity makes itself felt. For this reason it is logical to group together men who have at any time done six months or more at facework (which may include men actually doing surface or datal work at the time of the survey) rather than to divide men into surface and faceworkers on the basis of their present jobs.

Thus Cochrane *et al.* (1956) show that not only is there a higher prevalence of pneumoconiosis, particularly of P.M.F., in men working at the surface at the time of the investigation but that the proportion is higher still in ex-miners living in the same town. We have not been able to include ex-miners in our surveys but it seems reasonable to restrict arbitrarily the scope of the survey to those men actually employed at the pit at the time of the survey so far as they can be defined.

The proportion of men radiographed was 85% compared with 89% in Durham collieries. The same difficulty was experienced in both areas in determining with any degree of exactness the number of men actually employed at the collieries even when the pay roll was taken as a guide. As a result a number of men at each colliery are untraced because of insufficient information in the records or because they were casually employed, but it is likely that most of the regularly employed men were accounted for.

The impression obtained from out-patient work and compensation figures that there is less radiological pneumoconiosis in Northumberland than in Durham is confirmed by this survey. The average prevalence of all categories of pneumoconiosis in the men radiographed at these three Northumberland collieries is about 25% compared with 32% in four Durham collieries (McCallum and Browne, 1955), and in radiological categories 2 and over, the proportion in Northumberland (11%) is half that in Durham (22%). Progressive massive fibrosis in Northumberland is even less frequent in proportion, being about a fifth of that in Durham (Fig. 3).

These differences in prevalence in the two coalfields may result from different methods of working and seams worked, but two other fa tors might affect the recorded prevalence of pneumoconiosis in the Northumbrian coalfield. These factors both result from the wide use of mass miniature radiography (M.M.R.) in Northumberland where units have visited nearly all the pits at least once during the last few years. In Durham the four pits had not been visited by any radiography unit before our survey.

First, the proportion of men who attended for radiographic examination was 85% which is about 4% less than in the Durham survey. If there were more pneumoconiosis amongst the non-attenders than amongst those radiographed, then the true prevalence would be higher. In Northumberland, insufficient time was spent at the collieries and if the radiographic unit had been available for longer

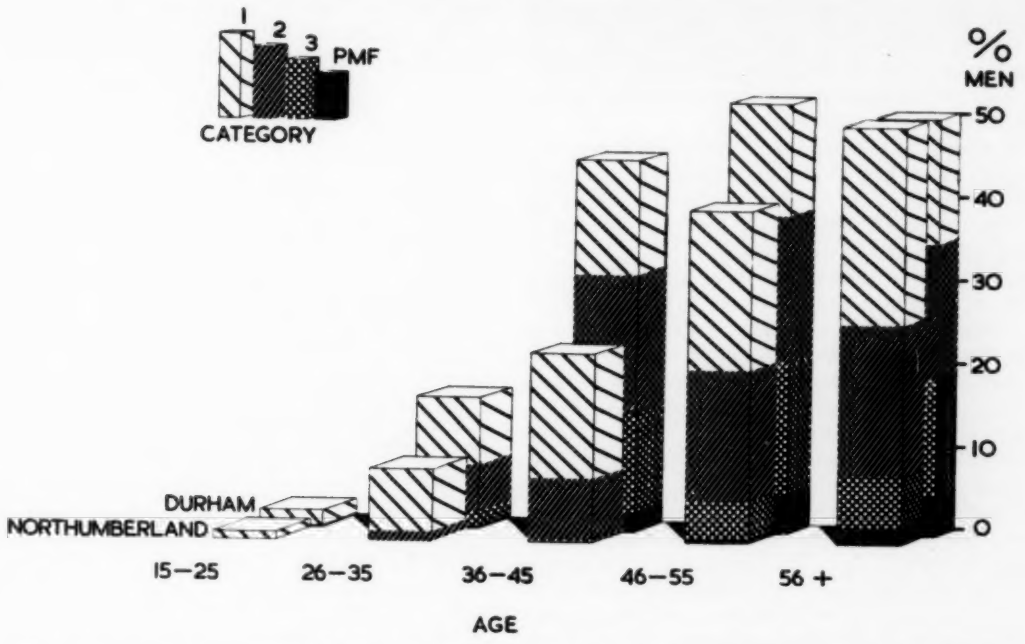

FIG. 3.—Prevalence of pneumoconiosis in four collieries in Durham and three collieries in Northumberland showing the radiological categories in each age group.

periods the number of non-attenders might have been appreciably less. But pneumoconiosis was not such a live issue amongst the Northumbrian miners as it was in Durham, perhaps because of a true smaller prevalence and of some degree of apathy at these collieries as a result of previous mass radiography. Secondly, the earlier visits of an M.M.R. unit could have led to the withdrawal of a substantial number of men with pneumoconiosis, especially those with Category 3 and with P.M.F. In general, however, the response to M.M.R. was poor and the recorded prevalence very low; and in the five years before these surveys only 11 men from these three Northumbrian pits were known to the National Coal Board (N.C.B.) as certified cases of pneumoconiosis. Only perhaps two-thirds of boarded cases are known to the N.C.B. so that if all the men boarded had been men with P.M.F. the number in that category would be more than doubled, but the proportion would still be only half that of Durham.

If all the men on the pay roll who were not radiographed (Table 15) are assumed to have normal lungs then 21·1% of all the men had some pneumoconiosis; if, on the other hand, half of the men not radiographed had pneumoconiosis of any category, then 27% of all the men are affected. About half these men not examined were probably faceworkers and if it is assumed that half of them have pneumoconiosis then the estimated true prevalence is 24%.

The exception to a generally much lower prevalence of radiological pneumoconiosis in Northumberland compared with Durham is in Category 1 where the proportion (13·7%) is actually higher than in Durham (10·3%).

In Durham the majority of the men certified by the Pneumoconiosis Panel in 1951-53 are over 35 to 40 years, whereas in Northumberland the level is about a decade higher at 45 to 50 years, so that not only is there less pneumoconiosis in Northumberland, but it comes to the notice of the Pneumoconiosis Panel rather later. In the two years (1951-1952) immediately before the survey six men were certified with pneumoconiosis from the three pits. This number rose to 57 in 1953-54 presumably as a direct result of the survey, as in the rest of Northumberland the corresponding rise over the same period was only from 95 to 126 men certified.

In the four Durham collieries surveyed in 1950-51 there was a tendency for the number of men in each category of pneumoconiosis to become stable at a certain level after a period of time; withdrawal from facework was associated with advancing age and particularly with P.M.F., and length of time at facework was associated with an increase in prevalence of radiological pneumoconiosis. The effect of facework became demonstrable after about 35 years of

age or 10 years at the face. Allowing for a difference in age at which heavy dust exposure began, there was a remarkable similarity between the proportion of men at different ages with pneumoconiosis in Durham and South Wales.

In these three Northumbrian collieries the percentage of miners with pneumoconiosis at age 20 years is small, as in Durham, and both begin to rise between 20 and 30 years of age (Fig. 4). The rise in Northumberland is progressively later than in Durham taking about five years longer to reach 10%, six years longer to reach 20%, and about 13 years longer to reach 40%. The difference is even more marked between Northumberland and the Rhondda Fach. This suggests that the Northumbrian mines have been much less dusty than either Durham or South Wales, or that there is some qualitative difference in the dust. At 60 years of age, however, the curves meet because the levels in Durham and the Rhondda Fach remain much the same after the age of 40 while that in Northumberland continues to rise. This high figure in Northumberland is largely due to the greater proportion of men in Category 1 than in Durham, for, if Category 2 and over is taken, Northumberland is 9% lower than Durham after 55 years of age (Fig. 3). The graph for Northumberland is practically linear (Fig. 4) even when Category 1 is excluded. The reason for this may be that withdrawals from the industry have been random and unrelated to the lung radiograph because most of the pneumoconiosis was not disabling.

Differences in age structure of the men at each colliery do not much affect the overall prevalence of pneumoconiosis. Although colliery *P* has fewer young men and more older men than *R*, they are very similar as regards prevalence of pneumoconiosis. In Northumberland withdrawals from facework increase with age, but in men with P.M.F. the numbers are so small that it is difficult to say that withdrawal has occurred for any reason other than age also. Six men with P.M.F. over 56 years of age are still working at the face but all the P.M.F. is in Category *A* from which disability is often slight. On the other hand, men in Categories *B-D* may well have left mining altogether because of more severe disability.

There are too few men under 35 years of age with pneumoconiosis to draw any conclusions about the importance of age or years at the face, but for the older men number of years at facework is more significant in increasing the radiological category than years of age.

Among the non-faceworkers with pneumoconiosis, screeners and blacksmiths have more men than any other group. Although most of these men had only

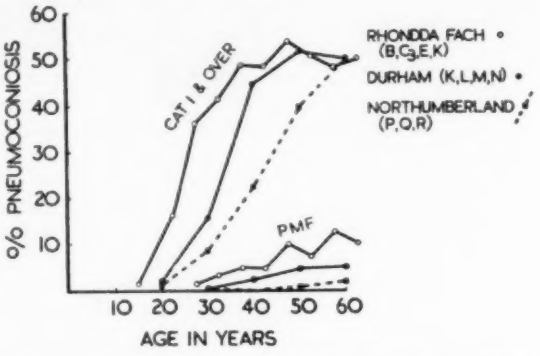

FIG. 4.—Percentage of pneumoconiosis of radiological category 1 and over in the Rhondda Fach (four collieries), Durham (four collieries), and Northumberland (three collieries). Progressive massive fibrosis is also shown separately. The Rhondda Fach figures refer to all underground workers while the Durham and Northumberland figures refer to all men employed at the collieries.

Category 1 changes it is clearly desirable to investigate and control the dustiness of those jobs.

The marked difference in prevalence of radiological pneumoconiosis in the adjacent coalfields of Durham and Northumberland may be explained by differences in working methods, which depend largely on the type of coal and ventilation. In Northumbrian collieries hand picks were replaced by mechanical cutters rather than by pneumatic picks as the coal is hard. In Durham, where the coal is more friable, pneumatic picks are common and bord-and-pillar work, in which efficient ventilation across the working area is difficult to achieve, is traditional. It has been shown, however, that in Durham dustiness relates to low seam height and rank of coal and not to method of working (Hall, 1956), and it is significant that in the deeper Durham pits nearly half the seams worked are less than 2½ ft. thick.

Summary

Prevalence data for radiological pneumoconiosis of coal-miners in Northumberland are given for the first time. Large (12 in. by 15 in.) radiographs of the chest were taken of 2,898 men, comprising 85% of the workers at three pits. Nearly 25% of the men had pneumoconiosis of radiological category 1 or more, and 11% had pneumoconiosis of category 2 or more. Progressive massive fibrosis was found in only 13 men (0·5%) and was all early (category *A*).

The wide use of mass miniature radiography in the same area for several years before this survey probably did not affect these figures.

Compared with the results of similar surveys in four Durham collieries there is much less pneumoconiosis of radiological category 2 or more in

Northumberland but there is about 5% more category 1 pneumoconiosis. The Northumbrian pits are found to have only a fifth of the progressive massive fibrosis found in Durham.

Prevalence of pneumoconiosis in Northumberland reaches the same levels as in Durham between five and 13 years later, and much later than in the Rhondda Fach, but at 60 years of age the prevalence is the same in all three areas. This may be because there is less disabling pneumoconiosis in Northumberland.

Pneumoconiosis of category 1 and occasionally of category 2 was observed amongst blacksmiths and screeners, who had done less than six months on facework, suggesting that the dustiness of these jobs requires control.

It is probable that more friable coal and a high proportion of low seams worked in Durham compared with Northumberland are the most important factors in the difference in prevalence of pneumoconiosis in the two areas.

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INDUSTRIAL DERMATITIS IN THE COAL-MINER*

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A group of coal-miners who had been certified as suffering from industrial dermatitis in the past has been reviewed. The object was to assess the degree of recovery and the effect of the skin trouble upon working capacity. A record was therefore prepared for each miner indicating (*a*) whether he had returned to his pre-dermatitis work; (*b*) whether he had had any further spells of absence due to recurrence; (*c*) whether troublesome signs and symptoms persisted which required treatment by his general practitioner. Coal-miners fall naturally into three major occupational groups, namely, face-workers, those employed elsewhere underground, and surface workers. These groups differ mainly in their place of work, the natural hazards to which they are exposed, and their rates of pay. It is interesting to compare the course of dermatitis and the reaction of the individual to this disease in the three occupational groups. The initial incidence of the dermatitis and the pattern of its distribution on the skin differed between the three occupational groups. Subsequently, however, dermatitis in all three groups appeared to behave in a remarkably uniform manner. The significance of this uniformity in relation to the aetiology of dermatitis is discussed.

Material and Method

The main environmental features of five collieries situated within a radius of five miles are indicated in Table 1. They are all large collieries employing over 1,600 men, with shaft depths from 474 to 750 yards. The majority of the seams worked are 3 ft. 6 in. or more in height, and the dry-bulb temperatures of the return air range from 68° F. to 79° F.

In the period reviewed 330 coal-miners were certified as suffering from industrial dermatitis under the Workmen's Compensation Act, 1925, or the National Insurance (Industrial Injuries) Act, 1946, at these five collieries. Eighty-two (24·9%) had left the district, and no further information about them was available. Two hundred and forty-eight (75·1%) continued to work at the collieries; all were seen personally for this investigation.

The time from the onset of dermatitis to review of the case was from one to three years in 110 men (44·2%), four to 10 years in 120 men (48·2%), and 11 to 17 years in a small group of 18 men (7·6%).

TABLE 1

MAIN ENVIRONMENTAL FEATURES OF COLLIERIES

Colliery	Average No. Employed in All Occupational Groups	Depth of Shaft (yd.)	Return Air Temperature (°F.)		Type of Mining	Seam Thickness (ft. in.)
			Dry Bulb	Wet Bulb		
A	1,637	716	79	71	50% power loading	Over 4 6
B	1,602	474	68	63	10% power loading	4 6 up to 1950 only then 3 0
C	1,703	721	72·5	68	11% power loading	3 6 upwards
D	1,725	750	74	68	90% power loading	4 6 upwards
E	1,600	550	72	68	66% power loading	4 6 upwards

TABLE 2

INCIDENCE OF DERMATITIS IN MAJOR OCCUPATIONAL GROUPS

Occupational Group	Specific Task	No. of Men with Dermatitis	Average No. at Risk	Rate per 1,000 at Risk
Coalface workers	Fillers	67	965	78·1
	Packers	25	590	42·3
	Rippers	41	590	69·5
	Deputies, Shotfirers, Others	32	1,180	27·1
	Total ..	165	3,325	49·6
Other underground workers	Haulage	31	1,160	26·7
	Maintenance (roads)	17	990	17·3
	Craftsmen	17	1,425	11·9
	Total ..	65	3,575	19·5
Surface workers	Total ..	18	1,720	10·4

*This paper was specially commended in the B.M.A. occupational health prize essay competition, 1957.

Occupation at Onset of Dermatitis

Table 2 gives the numbers of dermatitis cases reviewed in each occupational group related to the number at risk and rates per 1,000 at risk calculated for the main tasks within each occupational group. For every surface worker two employed elsewhere underground and five coalface workers were affected.

Coalface Workers.—Of coalface workers, fillers and rippers are those most prone to dermatitis. Rippers in coalface headings and in the fast ends of the coalface were more commonly affected than those working in the roadway where it entered the face.

The principal causative factors appear to be large quantities of dust and sweating. Packers who work on the back shift are not exposed to the same high dust concentrations and urgency of actual coal getting as fillers and rippers, although the pack-hole is hot. Packers can, however, step into cooler conditions in a very short space and they are less prone to dermatitis than are fillers or rippers. Other coalface workers are also less prone than fillers or rippers, but the difference between the other faceworkers and packers is not marked.

Other Underground Workers.—Haulage workers and road maintenance men have a somewhat higher rate than the remainder of other underground workers. This is probably explained by their exposure to coal dust at transfer and loading points, or to mixed dusts as the roadways are enlarged. In the miscellaneous group of craftsmen, pipe fitters and pump men predominate, possibly because they are frequently exposed to natural pit water which has a high chloride content.

Surface Workers.—In surface workers it is much easier to associate the occurrence of dermatitis with a particular incident or hazard, such as oil in the cutter-pick sharpener, carbon tetrachloride in coal preparation, and local heat in the stoke hole.

Distribution of Dermatitis on the Skin

The site of origin of the dermatitis, the sites to which it spread, and the sites of persistent skin trouble were recorded separately for each individual. The frequency with which each site was affected is expressed as a percentage of the total sites affected for each occupational group and the results are given in Fig. 1.

Some coal-miners were affected at several sites at the same time. The total number of sites affected, therefore, exceeds the number of men. The average number of sites affected per man indicates the approximate extent of the dermatitis and affords a useful index of comparison between occupational groups (Table 3).

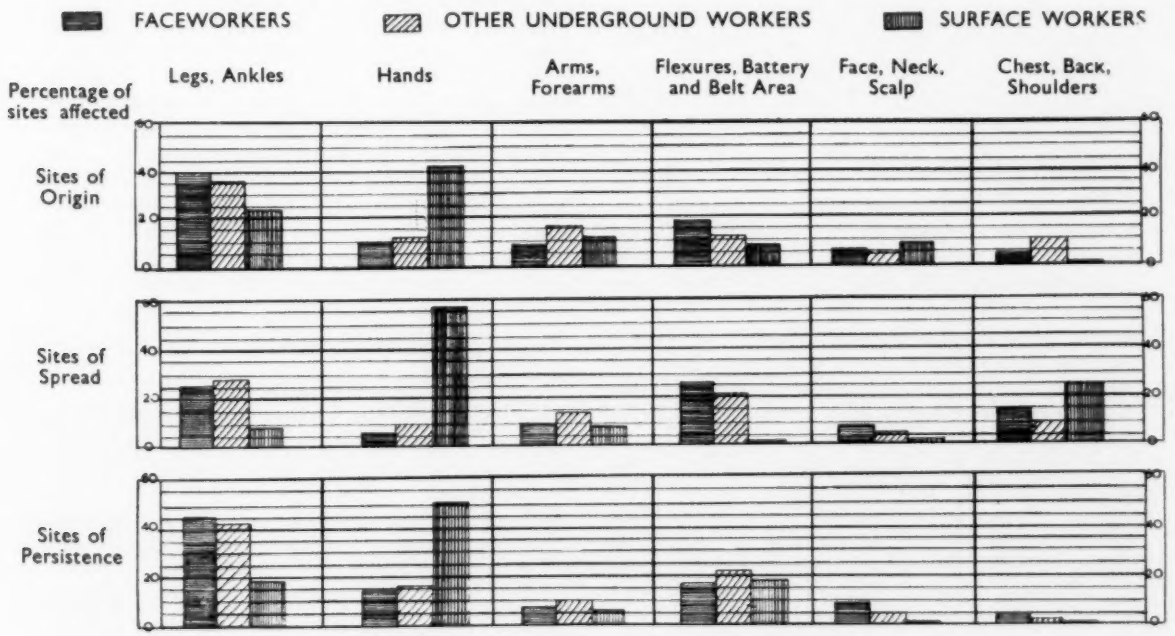

FIG. 1.—Diagram illustrating sites of dermatitis by occupational groups.

TABLE 3(*a*)
SITES OF ORIGIN OF DERMATITIS

	Coalface Workers	Other Underground Workers	Surface Workers	Total
Number of skin sites affected	223	95	24	342
Number of men affected	165	65	18	248
Average number of sites affected per man	1·3	1·4	1·3	1·3

TABLE 3(*b*)
SITES OF SPREAD OF DERMATITIS

	Coalface Workers	Other Underground Workers	Surface Workers	Total
Number of skin sites affected	171	78	10	259
Number of men affected	99	42	8	149
Average number of sites affected per man	1·7	1·8	1·2	1·7
Proportion of men with spread of dermatitis (% of those originally affected)	60·0	64·6	44·4	60·0

TABLE 3(*c*)
SITES OF PERSISTENCE OF DERMATITIS

	Coalface Workers	Other Underground Workers	Surface Workers	Total
Number of skin sites affected	142	44	16	202
Number of men affected	118	37	10	165
Average number of sites affected per man	1·2	1·2	1·6	1·2
Proportion of men with persistence of dermatitis (% of those originally affected)	71·4	56·9	55·6	69·0

Original Site.—The distribution of dermatitis was not the same in the three occupational groups. The hands were more frequently affected in surface workers than in underground workers. The reverse was true for the legs and ankles. The chest, back, and shoulders were relatively more affected in the other underground workers group, while the arms were relatively less affected at the coalface. The flexures, battery, and belt areas were more frequently affected in coalface workers. The extent of the dermatitis, however, as indicated by the average number of sites affected per man, was similar in all three groups (coalface workers 1·3, other underground workers 1·4, and surface workers 1·3).

Sites of Spread.—This refers to the areas of skin affected during the period following the origin at the site indicated. It does not include the site of recurrences. The sites of spread together with the sites of origin, therefore, indicate the extent of the initial attack of dermatitis. The same general pattern of distribution between occupational groups was present as in the original site distribution. Eleven coalface workers, five other underground workers, and two surface workers experienced generalized dermatitis not recorded in the table. Apart from these cases, 60% of all cases experienced some spread. Surface workers showed a somewhat lower tendency for dermatitis to spread (44·4%). If the extent of spread is compared in the occupational groups (Table 3b) by using the number of sites/number of men ratio, coalface workers (1·7) and other underground workers (1·8) both experienced more spread than surface workers (1·2).

When spread of dermatitis did occur in surface workers it was less extensive than in underground workers.

Sites of Persistence.—Some sites of the skin surface affected during the initial attack did not heal completely, leaving a chronic eczema. Others repeatedly broke down after recovery lasting at most a few weeks. On examination there was usually some form of dermatitis, and these sites were classified as persistent.

The overall distribution of the sites at which dermatitis persisted in each occupational group was similar to that of the sites of origin and spread. There was no special tendency for dermatitis to persist at any one site. Sixty-nine per cent. of the whole group of cases showed some persistence of dermatitis. There was a greater tendency to persistence among coalface workers (71·4%) than among other underground workers (56·9%) and surface workers (55·6%). The extent of the persistence on the skin surface was, however, less in underground workers; the ratio of number of sites affected to number of men was 1·2 for coalface workers and other underground workers compared with 1·6 in surface workers.

Conclusions

(1) The patterns of distribution of dermatitis in the three main occupational groups were broadly similar for sites of origin, sites of spread, and sites of persistence.

(2) The proportion of men who experienced some spread of dermatitis was less in surface workers than in underground workers.

(3) Surface and other underground workers showed less tendency to persistence than coalface workers.

(4) The extent of dermatitis at sites of origin was similar in the three occupational groups; surface workers had a less extensive spread but more extensive persistent sites than underground workers.

Subsequent History

Return to Pre-dermatitis Work.—Little information is available about the fate of the workman with industrial dermatitis after the initial attack. Morgan and Davies (1956*a* and *b*) reported that 68% of 26 cases reviewed 18 months after their first attack had returned to their former work. In the present group of 248 coal-miners, 139 (56·4%) returned to their former work. This proportion was maintained in the three main occupational groups. (Coalface workers, 90 out of 165 (55·7%), other underground workers, 40 out of 65 (61·5%), and surface workers, nine out of 18 (50%).)

Persistence of Dermatitis.—Of the 139 men who returned to their former work, 78 (56·1%) had had no further trouble with their skin (Table 4). Of the 109 who did not return to their former work, 47

TABLE 4

RETURN TO FORMER WORK RELATED TO PERSISTENCE OF DERMATITIS AND MAIN OCCUPATIONAL GROUPS

Occupational Group	Returned to Former Work		Not Returned to Former Work		Total	
	No. of Dermatitis Cases	No. Free from Dermatitis	No. of Dermatitis Cases	No. Free from Dermatitis	No. of Dermatitis Cases	No. Free from Dermatitis
Coalface workers	90	51 (56·6)*	75	30 (40·0)	165	81 (49·0)
Other underground workers	40	22 (55·0)	25	13 (52)	65	35 (53·8)
Surface workers	9	5 (56)	9	4 (44)	18	9 (50)
Total ..	139	78 (56·1)	109	47 (43·1)	248	125 49·1

*Percentages in brackets.

(43·1%) had had no further trouble. In all, 125 (49·1%) of the 248 were trouble free at the time of review, and they appeared to be evenly distributed among the main occupational groups.

Recurrent Spells of Absence due to Dermatitis.—Records were available of subsequent spells of absence lasting more than three days due to dermatitis (Table 5). One hundred and sixteen (46·4%) of the 248 coal-miners experienced such spells. The proportion of recurrences in each occupational group was similar: 74 (44·3%) of the 165 coalface men, 32 (49·7%) of the 65 other underground workers, and 10 (55·6%) of the 18 surface men. Those who returned to their former work were then separated from those who did not in order to assess

TABLE 5

RETURN TO FORMER WORK RELATED TO RECURRENCE OF DERMATITIS AND MAIN OCCUPATIONAL GROUPS

Occupational Group	Returned to Former Work		Not Returned to Former Work		Total	
	No. of Dermatitis Cases	No. of Men Experiencing Recurrences	No. of Dermatitis Cases	No. of Men Experiencing Recurrences	No. of Dermatitis Cases	No. of Men Experiencing Recurrences
Coalface workers	98	44 (49·9)*	67	30 (44·7)	165	74 (44·3)
Other underground workers	42	24 (61·5)	23	8 (35)	65	32 (49·7)
Surface workers	12	8 (67)	6	2 (33)	18	10 (56)
Total ..	152†	76 (50·0)	96	40 (41·7)	248	116 (46·4)

*Percentages in brackets.

†One hundred and fifty-two returned initially to their former work and 13 were found alternative work after a recurrent spell, leaving 139 as in Table 4.

the effect of this factor. Seventy-six (50%) of the 152 who returned to their pre-dermatitis work had a recurrence as against 40 (41·7%) of the 96 who did not return to their previous work. The incidence of recurrences was, therefore, only slightly reduced among those who found alternative employment. Of those who did not return to their former work, there was less likelihood of recurrence among surface and other underground workers than among coalface men. A change of work among coalface men did not appear to affect the incidence of recurrences appreciably (Table 5). Hellier (1958) similarly notes that in the case of primary irritants an employee who has developed dermatitis cannot escape by changing his work and advises that it might be better for him to continue in a job he knows rather than turn to fresh work where the chances of relapse may be almost as great.

Continued Treatment by General Practitioner.—Eighty-seven (36·6%) of the 248 coal-miners reviewed were still visiting their general practitioner for treatment at the time of review. The proportion in each occupational group was generally similar, namely, 55 (33%) of the 165 coalface men, 25 (38%) of the 65 other underground workers, and eight (44%) of the 18 surface men.

Summary

Two hundred and forty-eight coal-miners are reviewed from one to 17 years after the onset of industrial dermatitis. Of these 49·1% were trouble free and 46·4% had had a recurrent spell away from work due to dermatitis. Of those affected, 56·4% returned to their pre-dermatitis work. Return to former work did not appear to affect the chances of recurrence appreciably.

Coalface workers, especially fillers and rippers, were affected more commonly by initial attacks than other underground and surface workers. The probability of return to pre-dermatitis work and the persistence of dermatitis were broadly similar in the three main occupational groups.

Certain patterns of distribution of dermatitis on the skin of the body distinguished the main occupational groups in the initial attack. Similar patterns were evident in those with persistent dermatitis.

Adverse environmental factors may have accounted for the initial preponderance among coalface workers and determined the pattern of distribution on the body. Environmental factors did not, however, appear to affect the spread or persistence of the disease. Once initiated, dermatitis appeared to run a uniform course irrespective of occupational group or environment. The established patterns of distribution on the skin of the body do, however, persist.

I am very grateful to Dr. J. Trefor Watkins for his help and guidance in the preparation of this paper.

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LESIONS OF THE SKIN IN PROCESS WORKERS CAUSED BY CONTACT WITH BUTYL TIN COMPOUNDS

BY

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The industrial production of alkyl tin derivatives has increased rapidly in recent years, but little is known about the hazards to man which may exist in the handling of these substances. Interest in the matter has been sharpened by the catastrophic results of a therapeutic trial of one of the group, diethyl tin di-iodide, in the treatment of furunculosis. The compound was given orally and caused the death of 102 persons, cerebral oedema being found at necropsy (*British Medical Journal*, 1958). Many of those who survived were left with paraplegia or other permanent neurological damage.

As far as experimental work on animals is concerned, interstitial oedema of the white matter of the brain and cord was found by Magee, Stoner, and Barnes (1957) in rats poisoned by certain triethyl tin compounds. Stoner, Barnes, and Duff (1955) studied the toxicity of a number of alkyl tin derivatives for several species, and advised caution in the handling of organo-tin compounds, particularly of the ethyl series, because of the effect these substances had upon the central nervous system.

Barnes and Stoner (1958) showed that repeated application of dibutyl tin dichloride to the skin of the rat damaged not only the skin but also the biliary tract, proving that the compound was being absorbed percutaneously.

Present Investigation

This paper gives an account of the skin lesions seen among process and laboratory workers engaged in the manufacture of dibutyl and tributyl tin compounds.

Processing of Organo-tin Compounds.—Of the alkyl tin compounds made at Pure Chemicals Ltd., dibutyl and tributyl tin derivatives, with tetrabutyl tin, constitute the greater part and are alone considered here. Dibutyl tins are chiefly used as "stabilizers" in plastics and as polymerizers in silicone manufacture. Tributyl tins have been found effective against certain fungi (van der Kerk and Luijten, 1954) and are used as fungicides in paper making, paint manufacture, and in the preservation of timber.

The butyl tins are produced by a Grignard reaction from stannic chloride, magnesium, and a butyl compound in ethereal solution. The butyl tin salts may be either crystalline, or liquids of varying volatility, and nearly all are insoluble in water. In the course of manufacture men are occupied in manhandling carboys and flasks of reagents, intermediate and final products, and in the supervision of distillations, reaction vessels, and drying ovens.

Circumstances of Skin Contamination.—Chemical burns are most often found among those handling either dibutyl tin dichloride or tributyl tin chloride, especially the first which is an intermediate product in the preparation of dibutyl tin oxide, and is used in alcoholic solution. This solution is colourless, as is the liquid tributyl tin chloride, and, except when hot, it may fall unnoticed on the skin or clothes since the irritant effect of butyl tin derivatives is not apparent for at least an hour, and sometimes as much as eight hours.

The typical acute organo-tin burn only develops when the compound has been allowed to lie on the skin for more than a few minutes; it is found most often upon the face, hands, and wrists and is usually small. More extensive facial lesions have occurred as a result of splashing during sampling and general handling, but these have been less severe because the affected man has immediately washed.

Extensive and severe burns of the hand sometimes result either from working with gloves which have developed leaks or from failing to wear them.

Maintenance engineers and electricians may kneel or lie against a surface which is wet with one of the compounds and so develop burns of the knees and hip or arm. Such accidents are exceptional, the disregarded small splash being responsible for the great majority of typical lesions.

A more diffuse type of injury which heals less quickly than the acute burn is produced by prolonged contact with clothes moistened by vapour or by liquid spilt on the outside of vessels which are then manhandled. This type of injury is most commonly found where the clothes are in close contact with the skin of the ventral aspect of the body. Similar eruptions are found on the calves, level with the top of the protective Wellington boots issued to workers.

The Skin Lesions.—Only two kinds of eruption have been observed, the acute local burn and the subacute, more diffuse dermatosis already described.

Sensitization of the skin, with the development of eczematous types of eruption, has not been observed, even among men known to have become sensitized to other chemicals.

Acute Lesion.—The following is a description of burns produced experimentally on the skin of a group of five volunteers, none of whom had any connexion with the factory, or any previous exposure to organo-tin compounds. The experimental lesions were similar in each subject and were indistinguishable in appearance from the accidental burns found among workmen.

Tributyl tin monochloride was painted, undiluted and cold, on the skin of the back of the hand. There was no visible reaction till two to three hours later when some reddening and swelling of the mouths of the hair follicles could be seen, and the skin began to itch. Over the next eight hours the follicular inflammation became more intense, but the skin between the follicles was only very slightly affected, and there was only a minor degree of oedema. The pruritus was confined to the tested area and persisted for two or three days, but there was no pain. On the second day, minute pustules formed over some of the follicular openings, in the greatest numbers where the skin was most hirsute. The pustules remained very small and discrete until they dried up on the third or fourth day. The surface of the burn remained dry throughout. On the fifth day resolution was well advanced and after a week faint punctate erythema, with a little perifollicular scaling, was all that remained. The hair in the affected area did not subsequently fall out; on the contrary, in subjects who had been repeatedly tested with a number of compounds at the same skin site, the hair growth was unmistakably more vigorous there than at the corresponding point of the opposite limb.

Pus taken from a tiny pustule in one case presented no unusual appearances and no organisms were observed.

More extensive accidental burns are sometimes painful, but the degree of pain is never very great, itching being the principal symptom in every case. Healing is always rapid, and is usually complete within a week or 10 days.

Subacute Lesion.—The skin of the lower abdomen, thighs, groins, and perineum is particularly affected, more or less symmetrically. The chief complaint is of pruritus (the organo-tin worker can sometimes be recognized by his habit of absent-mindedly scratching one or other thigh as he works), which may be worse after a hot bath.

No obvious exudation takes place, but the complaint is made that the affected skin is slightly sticky so that the clothes, even when clean, tend to adhere to it.

On examination a faint erythematous eruption with well-marked demarcation from normal skin is seen. Hairy areas are most inflamed. The skin is abnormally friable and scratch marks are usually present. There is neither pustulation nor the characteristic folliculitis of the acute burn, the suffusion of the entire area being quite even. Removal of the patient from contact with organo-tins leads to rapid healing.

Butyl-tin derivatives have been prepared at Pure Chemicals Ltd. for over three years, but until a few months ago no workman had ever reported this type of skin disorder, and only one man has lost any working time on account of it. Protective aprons had not been worn, and it was found on enquiry that every man on the plant suffered in some degree from the condition. None of them was concerned about it, accepting an itch as something to be expected in a chemical works. Only one man later asked for treatment. The general view was that the skin gradually became " hardened ", so that the more experienced men had less trouble than the newcomers to the plant.

Accidents Involving the Eyes.—These are rare, since protective goggles are issued and their value is appreciated by process men. In the course of a year, the writer saw only one instance of splashing of the face during sampling from a carboy. The worker was not wearing goggles and both eyes were affected. Lachrymation and intense suffusion of the conjunctivae appeared within minutes, despite immediate lavage, and persisted for four days. At the end of a week there was still some erythema of the surrounding skin, but the eyes appeared normal.

TABLE 1

DETAILS OF ACCIDENTAL BURNS REPORTED IN A SAMPLE GROUP OF 15 MEN

Case No.	1	2	3	4	5	6	7
Site of burn	L. cheek	Hands	R. ankle	Legs	Eyelids, cheeks	L. leg	Brow, L. cheek, lower jaw
Size of lesions (in in.)..	½×1	5×4	3×2	2×2 2×1	approx. 2×2	2×1	5×2, 4×3, 1×1
Time taken to heal (in days)	4	*	3	3	4	3	4
Job	Dibutyl tin dichloride distillation	Maintenance	Dibutyl tin dichloride distillation	Tributyl tin oxide still	Cleaning carboys (fume)	Tributyl tin oxide still	Tributyl tin chloride distillation

*Case 2 did not report for follow-up examination.

Incidence of Accidental Burns.—Because most burns are small, almost painless, and resolve rapidly, they are not usually reported. Carelessness on the part of the workman is responsible for the majority of accidents, and this consideration doubtless predisposes a man to remain silent about his injury. As a rule, therefore, only the more extensive lesions come to light.

For the purposes of this survey, a group of 15 men who were engaged in the most hazardous jobs was asked to report every burn, however trivial, sustained during one normal working month. Unfortunately some of these people known to have had burns failed to report them. Table 1, therefore, is incomplete, and the true incidence of burns is somewhat higher than one per man per eight-week period.

Prophylaxis and Treatment.—Protective clothing, including long-sleeved polyvinyl chloride gloves, goggles, Wellington boots, and, where indicated, respirators, provides an effective defence against most accidents. Polyvinyl chloride aprons have been issued since the existence of the subacute type of eruption was recognized. The gloves are replaced at intervals because there is some uncertainty about the stability of polyvinyl chloride which is continually in contact with organo-tin compounds. Men are urged to wash well whenever they are splashed with these compounds, as this undoubtedly prevents the development of lesions.

Various applications have been used in the treatment of burns, but healing proceeds equally quickly in the treated and the untreated. Itching is relieved to some extent by the use of bland preparations such as oily calamine.

The Causal Agent

The butyl tins produced at Pure Chemicals Ltd. are stable under normal conditions, except that tributyl tin compounds break down slowly to their dibutyl equivalents in the presence of light, and the salts hydrolyze to the oxide in the presence of alkali.

It was thought at first that the halides alone caused burns, but skin testing, using a number of other dibutyl and tributyl tin derivatives specially prepared so as to be halide-free, disproved this. Table 2 shows the results obtained from testing each compound on the skin of a small group of volunteers. Liquid derivatives, or saturated solutions of crystalline ones in alcohol, were used to paint an area on the back of the hand about the size of a sixpenny-piece. Single applications only were made in each instance. Whenever any reaction occurred at all, the type of lesion was the same, but the amount of follicular inflammation and pustulation varied somewhat, being least in the case of tributyl tin laurate and most marked in that of tributyl tin chloride. The most slowly healing burn was that caused by tributyl tin acetate.

Dibutyl tin oxide is an almost inert substance, insoluble in water, alcohol, or ether, and was rubbed into the skin in powder form.

TABLE 2

ABILITY OF A GROUP OF BUTYL TIN COMPOUNDS TO CAUSE CHEMICAL BURNS IN MAN ON SINGLE APPLICATION

Dibutyl tin dichloride ..	+	Tributyl tin chloride ..	+
Dibutyl tin diacetate ..	−	Tributyl tin acetate ..	+
Dibutyl tin dilaurate ..	−	Tributyl tin laurate ..	+
Dibutyl tin oxide	−	Tributyl tin oxide ..	+
Dibutyl tin maleate ..	−	Tetrabutyl tin	−

Discussion

The lesions of the skin observed among men handling butyl tin compounds, though of common occurrence, are of minor importance as a source of complaint, and almost of no importance at all as a cause of absenteeism. In these respects, as in their appearance, they are similar to the burns reported among people working with antimony trichloride and trioxide (Schwartz, Tulipan, and Birmingham, 1957). Of greater concern than the burns themselves must be the potential danger of the percutaneous

absorption of butyl tin derivatives, especially in those cases with the subacute and diffuse dermatosis which is so prevalent. It seems that man is at least as sensitive, dermally, to organo-tins applied externally as the animals tested by Barnes and Stoner (1958), but, unlike the animals, none of the men has so far fallen sick with any illness which might be attributed to organo-tin poisoning.

The only general symptoms which have been consistently recorded are sore throat, cough, and retching which sometimes occur several hours after exposure to vapour or fumes. No chronic cough, and no physical or radiological signs have developed in the people who occasionally are exposed in this way. It seems likely that the symptoms are the result of irritation, with the characteristic delay in onset, of the mucous membranes of the pharynx and larynx.

It is concluded that some butyl tins, particularly of the tributyl series, are strong irritants of the human skin, and that the site of action is not on the surface but in the depths of the hair follicles.

It is probable that these substances are to some extent absorbed subcutaneously in man as in animals, and man may be more susceptible to poisoning by organo-tins than laboratory animals. We have no evidence that this is so, but the experimental evidence in animals, coupled with the therapeutic disaster with oral diethyl tin di-iodide referred to above, must be sufficiently disturbing to impel those interested in the commercial exploitation of organo-tins to do everything possible to protect workmen from contact with them. Adequate protective clothing and education of the men are measures of cardinal importance, which together should reduce the incidence of skin lesions and consequently the risk of systemic poisoning.

Summary

Certain organo-tins, notably of the tributyl series, cause skin lesions.

The lesions are of two types: (1) acute localized burns resulting from splashes falling on the skin, and (2) subacute irritation of large areas of skin of the trunk and thighs, caused by contamination of the clothes by vapour or spillings.

Neither eruption causes any appreciable loss of time at work; both are usually painless and heal without special treatment.

No evidence of any general toxic effects arising from absorption of butyl tin compounds has been found among workmen concerned in the processing of these compounds.

It is considered that, notwithstanding the apparent absence of long-term ill-effects either on factory economy, or on the workers' health, care should be taken to prevent skin contact with butyl tin derivatives.

My thanks are due to members of the management of Pure Chemicals Ltd. for their interest in this survey, for the provision of samples of butyl tin compounds, and for technical advice. I would also like to thank Dr. B. J. Leonard for his assistance with microscopy.

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CLIMATE AND HEALTH IN THE ROYAL NAVY

BY

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In July, 1945, a new form of monthly sickness return was introduced in the Royal Navy. The return called for counts of those men who were on the sick list, *i.e.*, incapacitated by sickness, and of those on the attending list, *i.e.*, with minor ailments who only attended the sick bay for treatment. It was expected that the attending list figures might be more closely related to living conditions than those for more serious illness necessitating absence from duty.

The first review of these returns (Roberts, 1948), covering the period August, 1945, to July, 1946, showed clearly the value of the attending list figures, and the sickness return was amended to require the inclusion of a record of the air temperature on the upper deck at noon.

The next examination, covering the period from October, 1948, to September, 1949 (Ellis, Smith, and Underwood, 1952), showed the value of the records of air temperature. When the returns from all stations were grouped together it appeared that the percentage of a ship's company on the attending list increased as the weather became hotter, and especially when the upper deck temperature exceeded 80° F. It was not clear whether variations in the numbers on the attending list were in some measure due to factors other than climate, such as station, or class of ship, so it was decided to make a further examination when more returns had been amassed.

In the present study, which covers the four years between October, 1948, and September, 1952, an examination has been made of the question whether the relation between minor sickness and climatic temperature is to be found in all classes of ship and on all foreign stations.

The Sickness Returns

About 12% of all the monthly sickness returns received contained obvious errors or could not be readily classified, and these were discarded. The remaining 1,855 were classified in respect to station thus:—

China	457 returns	Malaya	106 returns
Home	459 ,,	East Indies	98 ,,
Mediterranean	401 ,,	Persian Gulf	61 ,,
West Indies	140 ,,	Australia	4 ,,
South Africa	127 ,,	Red Sea	2 ,,

Air temperature measurements were given in 1,806 returns. Of these, 1,608 could be assigned to a particular station, the remaining 198 having been recorded while the ships were passing from one station to another. The number of returns received from maintenance and depot ships was 191 and in some instances, particularly where the effect of climate is considered, these have been excluded when the results have been grouped.

The returns were received from 104 different ships made up of four battleships, 12 carriers, 25 cruisers, 24 destroyers, 27 frigates and sloops, three minesweepers, four maintenance and repair ships, and five depot ships. For some purposes it was desirable to classify the ships in groups thus:—

1. Large ships (battleships, carriers, cruisers)
2. Small ships (destroyers, frigates and sloops, and minesweepers)
3. Maintenance and repair ships and depot ships

Of the 1,855 returns, 39·6% were from large ships, 49·4% from small ships, and the remaining 11% were from maintenance and depot ships.

The numbers on the sick list and on the attending list were subdivided according to the cause of sickness thus:—

(*a*) Skin diseases
(*b*) Injuries
(*c*) Upper respiratory infections
(*d*) Dysenteries and diarrhoeas
(*e*) All other diseases

The number of men on the attending list is expressed throughout as a percentage of the ship's company. The average value for each monthly return thus represents the average percentage of the ship's

company on the attending list for that particular month and is based on counts made at midnight every Wednesday. The complement was recorded at the beginning and end of the month and the average complement was taken as the mean of these two values.

The air temperature at noon was measured daily on the upper deck of the ship and recorded each week on the sickness return as the mean of seven observations. The monthly average temperature used in this report is the mean of these four or five weekly averages.

Results

Average Percentage of a Ship's Company on Attending and Sick Lists.—The average values for the percentage of a ship's company on the attending list and on the sick list for all ships on all stations for the four years under consideration were for the attending list 4·26% and for the sick list 0·54%.

The average percentage values of the various disease groups were:—

	Skin Disease	Injuries	Upper Respiratory Diseases	Dysenteries	All Other Diseases
Attending list ..	1·53	0·76	0·54	0·14	1·29
Sick list	0·08	0·10	0·16	0·03	0·17

The yearly averages were affected by the disposition of the various classes of ship throughout the world, but the variations from year to year were very small.

Effect of Climatic Temperature on Minor Sickness.—The number of men on the sick list is small compared with the number on the attending list, and only the figures for the attending list have therefore been used in examining the effects of climatic temperature on sickness. Skin disease was the group most affected by climatic temperature, and since accidents might well be likewise affected, these two groups have been considered in detail.

On some stations there were only smaller ships, and some classes of larger ships served on only one or two of the stations. Hence the comparison of the incidences of sickness in the separate classes of ship on the different stations is necessarily restricted.

Skin Disease.—The returns for the different classes of ship on the various stations showed that in small ships in the Mediterranean the incidence of skin disease indicated no clear trend with changing temperature, while in maintenance and repair ships on the Home Station there was some decline in that incidence during warm weather. In almost every other instance, whatever the station or the class of ship, there was an increase in skin disease as the weather became hot. Hence, in order to ascertain at what climatic temperature the increase in skin disease becomes significant some grouping of data is desirable. The incidence of sickness in maintenance and depot ships is not strictly comparable with that seen in the other classes, and they have therefore been omitted from the grouping.

The returns from all other ships when grouped for each station separately showed a rise in the incidence of skin disease with increase of climatic temperature. At temperatures above 75° F. the incidence of skin disease was much higher in the Persian Gulf than on any other station, while on the South Africa station the incidence of skin disease was generally somewhat higher than on the remaining stations other than the Persian Gulf. However, only 28 returns were received from the Persian Gulf, so that when the figures for all stations are combined the average incidence is affected only slightly by the inclusion of those returns.

Fig. 1 shows the incidence of skin disease in the various classes of ship irrespective of station. The general rise in incidence with increase in temperature is shown, although there is some variation of incidence between classes.

Further grouping of these results yields the curve, included in Fig. 2, which shows the general trend of the incidence of skin disease in relation to climatic temperature. Since the numbers on the attending list were determined weekly, the increase at the higher temperatures could be due to more men requiring medical attention, to a greater need for repeated attendances, or to both these causes.

Injuries.—A similarly detailed examination of the incidence of injuries was made. When for the different stations and classes of ship the incidence of injuries was plotted against climatic temperature no consistent relation with temperature was found, but there appeared to be a tendency for the incidence to increase in the hottest climates. The result of grouping the available returns from all ships except maintenance and depot ships is included in Fig. 2.

All Causes.—Fig. 2, which summarizes the returns from all ships other than maintenance and repair ships on all stations, shows the percentage on the attending list from all causes, and also the percentage due to the five separate disease groups in relation to upper deck temperature. The figure represents the general trend of minor sickness in H.M. ships, although in some classes, *e.g.*, cruisers and frigates, and on some stations, *e.g.*, the Persian Gulf and South Africa, the incidence at any temperature is likely to be higher than that indicated by the curve.

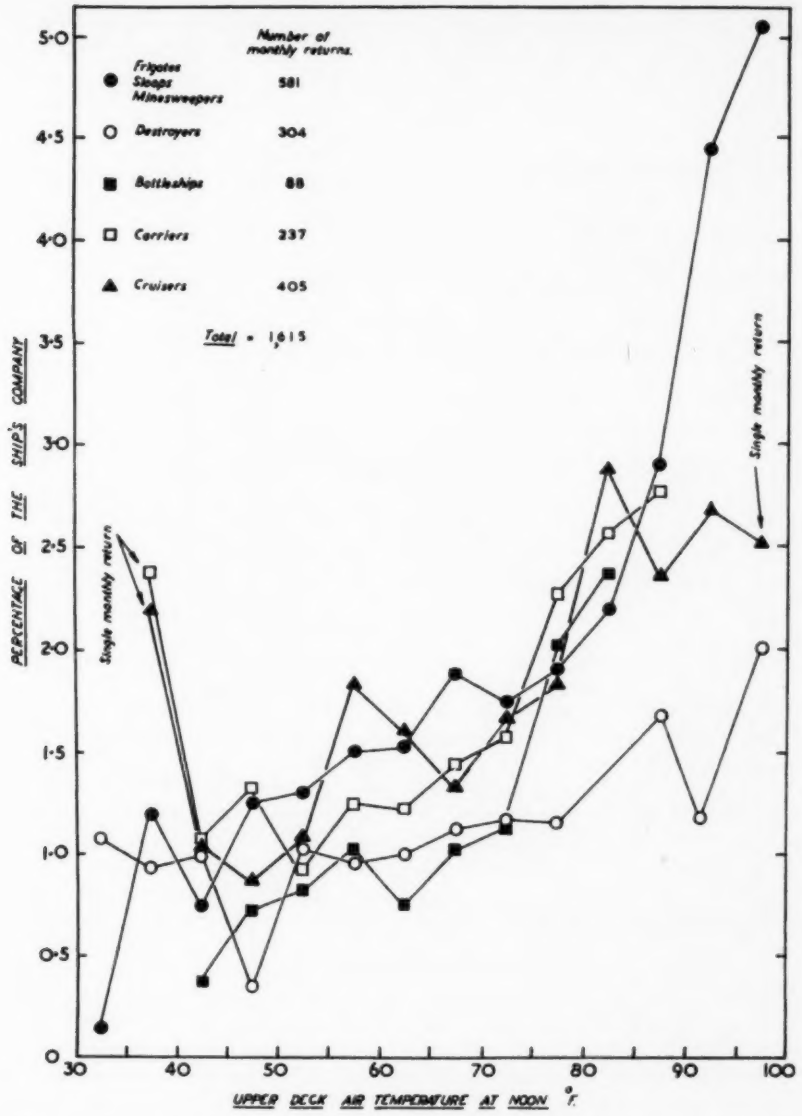

FIG. 1.—The percentage of a ship's company on the attending list with skin disease given as the average value for each class of ship, irrespective of the station on which they served, and the upper deck air temperature at noon.

There is a steady increase in minor sickness as the temperature rises. The increase is most noticeable in respect of skin disease and to a less extent in " all other diseases ", while with injuries the rise is only slight. With skin disease and with total sickness a pronounced increase occurs when the climatic temperature exceeds 80° F., and when 90° F. is exceeded the increase is very striking, although it is to be noted that the number of observations at temperatures above 90° F. is small. Dysenteries normally account for but a small number of men on the attending list (0·1%), but the proportion increased to about 0·3% in tropical weather. In cold weather upper respiratory diseases tend to increase, and a slight increase in the other disease groups, with the exception of dysenteries, is seen in very cold weather.

The composition of the total attending list at

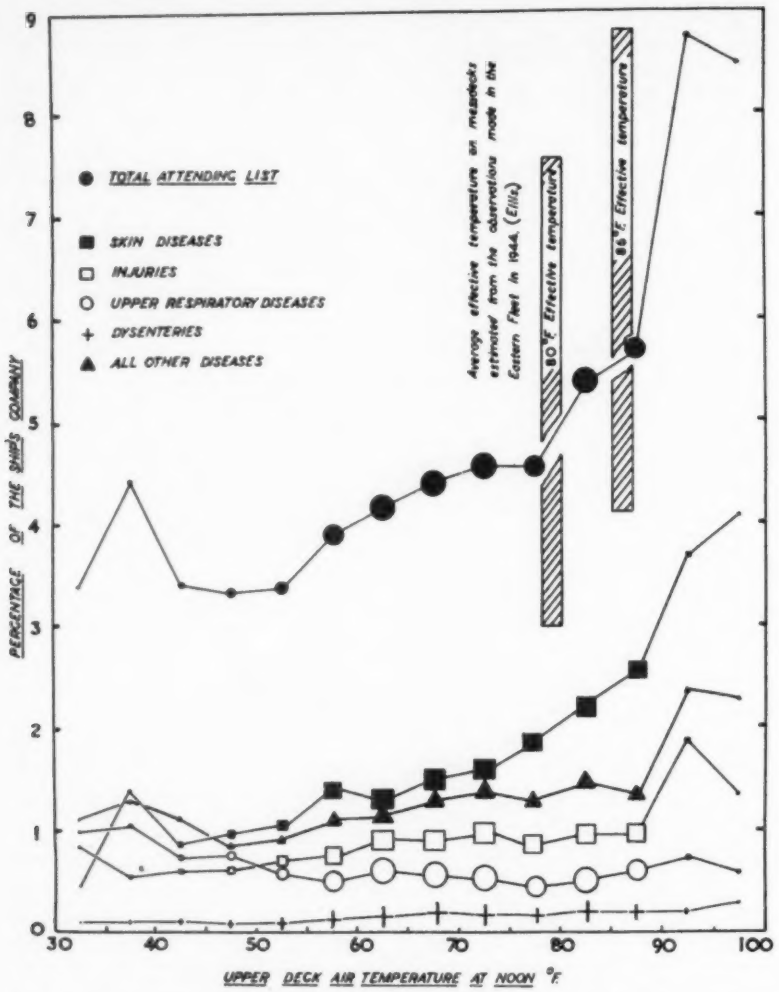

FIG. 2.—The percentage of a ship's company on the attending list given as the average value for all ships (except maintenance and repair ships) on all stations, and the upper deck air temperature at noon.

(The area of each point plotted in the diagram is proportional to the number of monthly returns from which the average was calculated.)

given ranges of upper deck temperature is given in Table 1. By far the most important group is skin diseases, which account for 30% of the attending list even in temperate waters, and for nearly half of it in very hot climates. In very cold weather upper respiratory diseases account for 23% of the total attending list, whereas the proportion is reduced to only 7% in very hot weather. Dysenteries, although tending to increase in number in hot weather, account for a very small proportion of the total attending list, injuries account for nearly one-fifth of the total, and all other diseases for rather less than one-third.

Effect of Air-conditioning on Incidence of Sickness on Attending List in Sloops.—In attempting to assess the effect of air-conditioning on the incidence of sickness it is preferable to consider individual ships and to compare directly the incidence of sickness before and after the installation of air-conditioning equipment under the same climatic conditions on the same station. H.M.S. Wildgoose was air-conditioned in April, 1952, and H.M.S. Flamingo in October, 1949, and the returns received from these sloops permit direct comparisons to be made for periods when the ships served in the Persian Gulf. Sickness returns were also received

TABLE 1

PROPORTION OF MEN ATTENDING THE SICK BAY ATTRIBUTABLE TO VARIOUS DISEASE GROUPS

Upper Deck Air Temperature at Noon (°F.)	% Attending Sick Bay	Proportion (%) of Total No. Attending Sick Bay				
		Dysenteries	Upper Respiratory Disease	Injuries	All Other Diseases	Skin Disease
30–39	4·13	2·3	22·9	15·3	31·9	27·6
40–49	3·31	2·2	22·3	18·6	28·8	28·1
50–59	3·64	2·8	14·6	19·8	28·7	34·1
60–69	4·23	3·3	13·6	20·9	29·1	33·1
70–79	4·52	3·8	10·4	19·4	29·0	37·4
80–89	5·45	3·7	10·0	17·2	25·8	43·3
90–99	8·64	2·9	7·0	19·4	27·1	43·6

TABLE 2

COMPARISON OF PERCENTAGE OF SHIP'S COMPANY ON ATTENDING LIST BEFORE AND AFTER AIR-CONDITIONING IN SLOOPS

Ship and Station	No. Monthly Returns	Average Climatic Temperature		Before or After Installation of Air-conditioning	Percentage of Ship's Company on Attending List with					
		Wet-bulb (°F.)	Dry-bulb (°F.)		Upper Respiratory Disease	Dysenteries	Skin Disease	Injuries	All Other Diseases	Total
"Wildgoose"	6	83·2	92·5	Before	0·73	—	7·43	2·16	0·74	11·06
Persian Gulf	5	84·6	93·6	After	0·31	0·08	4·20	0·25	0·64	5·48
"Flamingo"	5	81·2	94·0	Before	0·97	0·65	4·75	2·82	3·08	12·27
Persian Gulf	6	80·7	91·3	After	0·59	0·02	3·06	2·27	2·62	8·56
"Wildgoose"	1	83·0	89·0	Before	—	0·20	3·27	2·09	0·46	6·02
East Indies	1	83·0	88·0	After	—	0·05	1·53	0·90	0·63	3·11
Both sloops	12	82·4	92·8	Before	0·77	0·29	5·97	2·43	1·69	11·14
Both stations	12	82·5	92·0	After	0·42	0·05	3·41	1·31	1·63	6·82

from H.M.S. Wildgoose while she served on the East Indies Station, but only single monthly returns are available for comparison.

The comparisons made in Table 2 leave little room for doubt about the beneficial results of air-conditioning when ships serve on hot stations. When the figures for both sloops are pooled it appears that, with average climatic conditions that were virtually identical, the incidence of skin diseases and of injuries were respectively 43 and 46% less with air-conditioning than without it, while the total attending list was reduced by 39%.

Discussion

Incidence of Sickness and Standards of Environmental Warmth.—During the last war the high air temperatures and humidities in H.M. ships serving in tropical waters caused some concern, and the Royal Naval Personnel Research Committee was invited to define standards of environmental warmth which were compatible with the health and efficiency of the men. The Committee selected the effective temperature scale as the basis for its recommendations, and provisionally suggested that an effective temperature of 80° F. was the upper desirable limit, and that 86° F. was the highest effective temperature that could be accepted. From the standpoint of the men's efficiency the results of much research carried out since that time have generally supported this recommendation. Nevertheless, little information has been available to show whether health is impaired when these levels of warmth are exceeded for any length of time.

Our sickness returns record the temperature on the upper deck, but, by using the results obtained by earlier observers, it is possible to deduce from the upper deck temperatures the effective temperatures on the mess decks where the men live. A comprehensive survey of the thermal conditions in ships of the Eastern Fleet (Ellis, 1945) showed that on the average, in ships in the tropics, the internal air temperature was 8° F. above the outside air temperature, the wet-bulb depression was about 9° F., and the air speed about 90 ft. per min. Using these average values it can be computed that the general relation between the effective temperature on mess decks and the air temperature on the upper deck was that shown by the line in Fig. 3, in which the individual points represent the average values for various ships.

Of particular interest in this discussion are effective temperatures between 80° F. and 86° F. According to Fig. 3 these effective temperatures would be reached on mess decks with external air temperatures of about 78° F. and 85° F. respectively. These two temperatures have been indicated in Fig. 2.

The observations in the Eastern Fleet were made

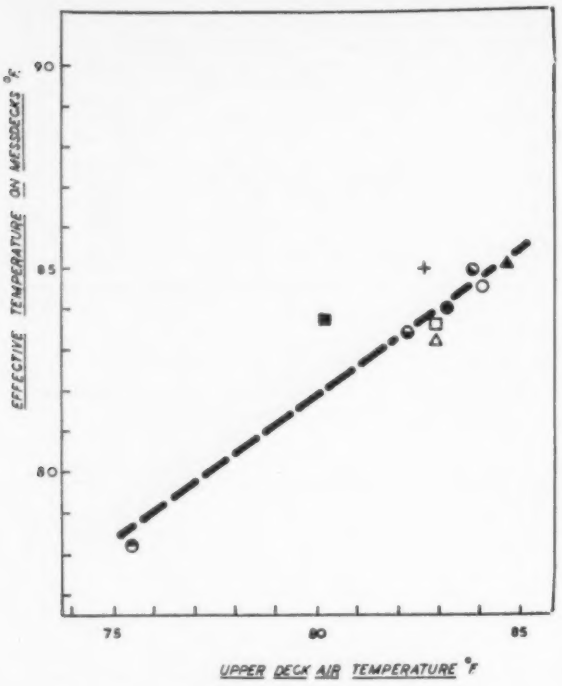

FIG. 3.—Estimate of the average effective temperature on mess decks generally for given upper deck air temperatures derived from 1,132 observations made in the eastern fleet in 1944.
(The plotted points are the averages of the observed values in eight ships. Three of the points represent measurements in the same ship on different occasions.)

during the war when ships were blacked out, whereas our returns relate to peace-time conditions. With a given upper deck temperature the temperature within a ship is therefore likely to be somewhat lower than in a similar ship during war. Yet even if the internal effective temperatures of 80° and 86° F. are associated with external air temperatures of, say, 80° and 87° F., the general conclusion is unaltered. Effective temperatures exceeding 80° F. are highly undesirable.

Effect of Air-conditioning on Minor Sickness in Sloops.—The direct comparisons which have been made between the incidence of sickness in individual sloops in the Persian Gulf before and after air-conditioning have shown clearly that with similar external conditions sickness was reduced considerably when the living spaces were air-conditioned. However, those comparisons give no indication of either the range of climatic conditions experienced in the Gulf during the course of a year, or of the incidence of sickness, and the effect of air-conditioning on it, at the different seasons. Hence they do not indicate fully the severity of living conditions in the Persian Gulf or the amelioration that results from air-conditioning. This information can be obtained by combining the figures relating to the two sloops (Table 3).

Table 3 shows the average climatic conditions observed at noon for each month of the year. It also shows for two-monthly periods the incidence of minor sickness before and after the air-conditioning of the living spaces. The high percentage of the ships' companies who during the hottest months were compelled to go to the sick bay for treatment for skin diseases when there was no air-conditioning reflects the severity of the conditions that prevailed. After air-conditioning had been installed the number of men who required treatment for skin diseases was greatly reduced, and it is reasonable to suppose that the much larger percentage of the men who had earlier suffered from prickly heat, but not badly enough to warrant going to the sick bay, must also have been much reduced as a result of air-conditioning.

Ventilation Standards and Incidence of Minor Sickness.—In view of the relation between minor

TABLE 3

AVERAGE MONTHLY CLIMATIC CONDITIONS OBSERVED IN PERSIAN GULF AND INCIDENCE OF MINOR SICKNESS FOR TWO-MONTHLY PERIODS IN SLOOPS WITH AND WITHOUT AIR-CONDITIONED MESS DECKS

Month	Average Conditions on Upper Deck at Noon			% Ship's Company on Attending List with and without Air-conditioning			
				For Skin Diseases		For All Causes	
	Dry-bulb Temperature (°F.)	Wet-bulb Temperature (°F.)	Relative Humidity (%)	Without	With	Without	With
January	64	60	80	1·81	1·16	5·66	5·59
February	68	63	76				
March	73	68	78	3·68	2·26	7·18	5·50
April	80	74	76				
May	90	80	65	5·45	4·31	11·57	7·43
June	94	82	60				
July	95	84	64	6·91	3·79	12·04	6·18
August	96	83	58				
September	93	82	63	6·60	4·72	11·07	9·35
October	89	79	65				
November	80	71	65	5·91	1·45	9·49	6·34
December	70	64	73				

sickness and climatic conditions and of the apparent effects of air-conditioning, it is of interest to consider whether minor sickness is likely to be reduced appreciably by improved standards of ventilation without the use of mechanical refrigeration. For ships that are not air-conditioned the naval constructor designs the ventilation equipment to cope with an external air temperature of 88° F.

On some stations, *e.g.*, Malaya, East Indies, and West Indies, even if ventilation lavish enough to keep the inside of the ship at virtually the same temperature as the outside air could be provided, effective temperatures in excess of 80° F. would occur very commonly. At such effective temperatures there is an increased incidence of minor sickness, so that merely to increase the rate of ventilation would not give satisfactory results.

If minor sickness is to be reduced appreciably when ships serve on foreign stations it seems that air-conditioning of the living spaces, and of the working spaces where possible, will be needed. An impression of the reduction in minor sickness which might be expected to result from the air-conditioning of living spaces can be gained from inspection of Fig. 2. It may be argued that the numbers on the attending list would be lowered only by perhaps 2% of the ship's company, and that this is but a small proportion. Yet such an argument can be misleading, for besides those who attend the sick bay many men suffer from skin diseases in hot weather who are not driven to seek attention.

For every man attending the sick bay from this cause many more will probably be very uncomfortable with prickly heat. Hence a statement that 5% of the ship's company were on the attending list with skin disease gives an inadequate notion of the discomfort that was being experienced. If the 5% could be reduced to, say, 2½%, far more than 2½% of the ship's company would be likely to gain considerable relief, and all would undoubtedly be far more comfortable.

Summary

Increased minor sickness during hot weather is seen on all stations and in all classes of ship which it has been possible to examine. When the climatic temperature at noon was about 60° F. 3% of the ship's company were on the attending list. This proportion increased to 5% at 80° F., and to about 9% when the temperature was above 90° F. Except in the Persian Gulf air temperatures above 90° F. were rare.

In the Persian Gulf the effect of air-conditioning sloops was striking. The attending list figures decreased from about 11% to about 7% of the ships' companies, while the incidence of skin disease was reduced by almost one half.

It is estimated that the effective temperature on mess decks will reach 80° F. when the external temperature is about 80° F., and the increase of minor sickness at external temperatures above 80° F. supports an earlier opinion that an effective temperature higher than 80° F. in ships is undesirable.

On most foreign stations climatic temperatures so often exceed 80° F. that ventilation alone cannot be relied upon to keep the thermal conditions in ships down to recommended standards. This can be done only by air-conditioning.

The encouragement, help and advice given so readily on many occasions by Dr. T. Bedford and Dr. J. A. Fraser Roberts are very gratefully acknowledged.

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THE EMOTIONAL STABILITY OF MINERS WITH NYSTAGMUS

BY

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The theory has long been held that coal-miners' nystagmus is a psychosomatic disease (Culpin, 1925; Halliday, 1943). The Miners' Nystagmus Committee of the Medical Research Council (1922) originally suggested that the disease was solely the result of deficient illumination but later (1932) concluded that in the treatment of the disease it was chiefly the psychological factors which predominated. Moreover, they pointed out that many of the symptoms of miners' nystagmus, such as photophobia and blepharospasm, occurred where there was no ocular abnormality, and ophthalmologists diagnosed them as hysterical.

Browne (1951) has shown that cats develop nystagmus when kept in the dark, which suggests that lack of illumination is important in producing nystagmus. However, the fact remains that not all miners (or indeed all cats) develop nystagmus and individual psychological differences may well account for this.

Previous attempts to investigate this problem have been based either on subjective assessments by physicians or have been concerned with what is social rather than psychological. It was felt, therefore, that a more objective study would be of value. As a result of the work of Eysenck (1947) and more recently that of Heron (1956), several tests of emotional instability have been devised which have a high measure of reliability. These tests, which have been tried out on many thousands of subjects, have been shown to discriminate between the normal and neurotic, as diagnosed by psychiatrists.

The aim, therefore, of this study is to compare two groups of miners, one group with nystagmus and one without the disease, and to establish by means of a battery of objective tests of emotional instability whether there is a difference between them.

Selection of Groups

Men with Nystagmus.—Sixty-seven miners were selected (using a random number table) from a list of men who had all been certified by the same physician as having nystagmus. The average age of these men was 53 years. They were all faceworkers and had spent an average of 25 years at the coalface.

Controls.—These men, also randomly selected, were being used as part of a study of pneumoconiosis and their chest radiographs had shown different radiological categories. All the men in both groups worked in the Durham coal field. In order that there should be no bias in the group, the number of men in each radiological category was matched against the frequency distribution of radiological categories in that coal field (McCallum, Browne, and Campbell, 1955). Later an analysis of variance revealed no significant difference between any of the radiological categories on any of the tests.

Seventy-four men out of a possible 101 attended. Seven were rejected as they were unable to perform one of the tests (leg persistence) due to some physical disability. The relatively large number of men who did not attend when requested was due to their not being compensated for loss of shifts, and indeed many of those who did come lost earnings. It was realized that there might be some bias due to self-selection on the part of the men, but a comparison of those men who came on receiving the first letter and those who came only after two or three letters showed no significant difference on any of the tests. The average age of the 67 men who formed the control group was 55 years and they had spent an average of 30 years working at the coalface. All the men were tested at the Nuffield Department of Industrial Health.

The Tests

A small battery of tests taking 30 to 40 minutes to administer was used.

Two-part Personality Inventory (Heron, 1956).—This, the chief test used, is a questionnaire test consisting of 74 statements concerning physical health, so giving the impression of being an health inventory. The score is based on 18 of these items considered to reveal emotional instability (or neuroticism) when scored in the appropriate direction. In the original inventory there are 20 significant items but owing to the close resemblance of two of these to the symptoms of nystagmus it was decided to omit them from the test. The omitted phrases

were " My eyesight is sometimes blurred " and " I have no particular physical or health problems ".

This test has been validated on more than 1,600 people and has a misclassification rate of only 13%. This means that 87 out of 100 patients diagnosed as neurotic by a psychiatrist would be likely to obtain neurotic scores on this test.

The second part (Heron II) gives a score of sociability dependent on 12 of 36 items.

The remaining tests were as follows:—

Food Aversions (Wallen, 1945).—This is scored as the number of aversions recorded from a list of 24 items of food. Wallen has shown that neurotics generally record a significantly larger number of aversions than others.

Annoyances (Bennett, 1945).—This test records the number of items which the subject chooses as annoying him from a list of 60 possible annoyances.

Hand Persistence (Eysenck, 1947).—This test records the number of seconds the subject can maintain his grip on a hand dynamometer at two-thirds of his maximum grip. The score is the best of two trials, once with each hand. Neurotics have been shown to have less persistence than others.

Leg Persistence (Eysenck, 1947).—This test is a measure of the number of seconds a subject while seated can hold his right leg fully extended at a given distance above a chair. As with hand persistence neurotics are said to have less persistence than others.

Fluency (Eysenck, 1947).—The subject is asked to name as many " round objects " as he can in one minute. Neurotics tend to be less fluent than others.

Results

Table 1 shows the mean scores for both groups on the seven tests with the appropriate levels of significance. On four out of six tests of emotional instability the men with nystagmus obtained significantly more neurotic responses than the controls, and all were in the expected direction.

TABLE 1
COMPARISON OF MEAN SCORES BETWEEN MEN WITH NYSTAGMUS AND CONTROLS

Test	Mean Score of Men with Nystagmus (N = 67)	Mean Score of Control Miners (N = 67)	t (with 132 d.f.)	Level of Significance
Heron I—emotional instability	9·63	7·81	3·02	$P < 0·01$
Annoyances	39·93	37·08	1·07	n.s.
Food aversions	5·85	4·51	2·24	$P < 0·05$
Hand persistence	46·67	57·49	2·28	$P < 0·05$
Leg persistence	38·43	60·36	2·80	$P < 0·01$
Fluency	7·15	7·18	0·06	n.s.
Heron II—unsociability	6·46	5·91	1·26	n.s.

On Heron I, the main test of emotional instability, Student's t test (132 d.f.) revealed a significant difference ($P < 0·01$). Food aversions and hand persistence discriminated at the 0·05 level of significance and leg persistence at the 0·01 level.

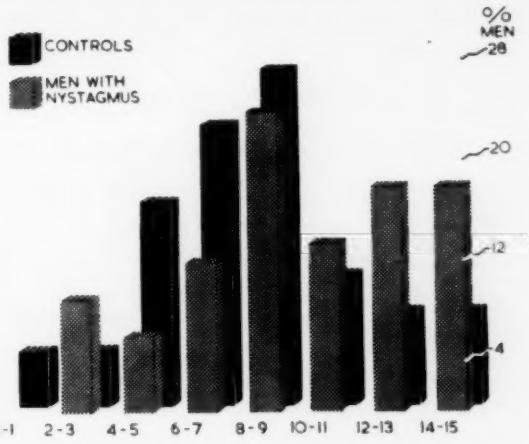

FIG. 1.—Histogram of results of instability test (Heron I) in subjects and controls.

No significant difference appeared on the annoyances and fluency tests, and this was also true of Heron II, the test of sociability. (It is intended to show in a further paper that the two former tests when included in this battery have very small loadings on a factor of emotional instability.)

Fig. 1 demonstrates the difference between the two groups on Heron I, showing the higher percentage of men with nystagmus at the high scores and the greater percentage of controls at the low scores. Heron considers those with scores of 0 to 7 as " probably well adjusted ", scores of 8 and 9 as " doubtful ", and over 10 as " probably maladjusted ". In a parallel investigation on emotional instability in underground workers the present author found that miners obtained significantly higher scores on Heron I than workers in another industry, a finding which is consistent with that of Heron and Braithwaite (1953). This explains the relatively high scores obtained by the control group.

TABLE 2
COMPARISON OF MEAN SCORES ON HERON I FOR THREE GRADES OF NYSTAGMUS

Grades	Number of Men	Mean Score
1 (Mild)	28	9·14
2 (Moderate)	25	10·12
3 (Severe)	14	10·14

Severity of the disease was rated by the certifying physician who had no knowledge of the scores obtained. It will be seen from Table 2 that on Heron I the difference between the mean scores of the three groups is small, and an analysis of variance disclosed no significant difference, *i.e.*, there was no

concomitant rise in degree of emotional instability with severity.

TABLE 3

LACK OF RELATIONSHIP BETWEEN DURATION OF NYSTAGMUS AND EMOTIONAL INSTABILITY ON HERON TEST I

	Duration of Nystagmus in Years				
	0–4	5–6	7–8	9–10	11 and over
Number of men	6	18	23	9	11
Mean score (Heron I)	7·7	10·4	9·6	10·9	8·5

There was no evidence of any relationship (see Table 3) between emotional instability and duration of the disease.

Discussion

The majority of these tests of emotional instability have shown a significant difference between the two groups, thereby suggesting that men with nystagmus are more emotionally unstable than men without the disease. It should be stressed that this is the first time a study of the disease has been made using carefully standardized tests. All the findings have been based on objective tests and the results confirm the opinion that psychological factors play an important part in the disease.

The results of Heron's test part II (see Table 1), which shows that there is no difference in sociability between miners with nystagmus and controls, agrees with the findings of Browne and Beck (1954). But, whereas they concluded that there was no difference at all between the two groups, it appears that while being as sociable as the controls, men with nystagmus do show other psychological differences.

However, a basic problem still remains: Which appears first, the nystagmus or the emotional instability ? Is it the case, as Culpin (1925) suggested, that the nystagmus is of purely physical origin and itself precipitates a neurosis, or does the neurotic personality predispose a miner to develop the disease ?

Dorothy Campbell (1948) has suggested that the worry and unemployment resulting from nystagmus may encourage the development of neurosis. But, in this study, which was made in a time of almost full employment in the pits, only six of the 67 men with nystagmus were in fact unemployed and therefore the high scores obtained cannot be attributed to the stress of unemployment.

However, it should be pointed out that only two of the men with nystagmus had returned to their original jobs at the coalface, the remainder being employed in surface work at which they were earning approximately half their previous wages. It would be interesting to compare a group of disabled men from another industry, who were similarly earning much less than their original income, and see whether they obtained high emotional instability scores. This would indicate to what extent the instability is caused by the financial stress resulting from nystagmus or indeed any other disease.

The only way to solve the basic problem of which comes first would be a long-term and large-scale investigation in which all men entering the pit would be given these tests, their scores recorded, and several years later an analysis made of the scores of those men who subsequently developed the disease. In this way it should be possible to determine whether the nystagmus superimposed on a latent emotional instability precipitates a neurotic crisis, or if lack of stability is a factor in causing nystagmus.

With greater improvement in lighting conditions in the pits the incidence of nystagmus is declining, nevertheless, the problem still remains as to why some men develop the disease and others do not.

Summary

Sixty-seven men suffering from coal-miners' nystagmus and the same number of control miners were compared on a battery of objective tests of emotional instability.

On four out of six tests the men with nystagmus scored significantly more neurotic responses than the controls. All six tests showed a difference in the expected direction between the two groups. It was found that the men with nystagmus were not less sociable than men without the disease. Neither the severity of the disease nor its duration correlated with emotional instability.

This study confirms the view that men with nystagmus are more emotionally unstable than men without the disease.

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BY

S. M. WOODCOCK

From Barnet General Hospital

(RECEIVED FOR PUBLICATION NOVEMBER 11, 1957)

Chronic mercury poisoning treated with calcium disodium versenate ($CaNa_2E.D.T.A.$) has not previously been reported in England.

In this case treatment with 2 : 3 dimercaptopropanol (B.A.L.) and $CaNa_2E.D.T.A.$ was used and the effect of these on urinary mercury excretion was compared.

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The patient was a girl of 24 who had worked for six months in a factory "throwing" coils. This process consisted of calibrating coils containing mercury for use as pressure gauges. On an average, two or three coils a day burst during testing, so that the work bench was usually contaminated with metallic mercury. Despite warnings about the danger of ingesting mercury, she ate sweets at work and had a habit of sucking her fingers. She had felt unwell for about a month before admission, with general lassitude, anorexia, and loss of weight. She had noticed a metallic taste in her mouth but denied excess salivation and her teeth and gums were healthy. She was admitted to hospital on July 6, 1957, oedema of the ankles, hands, and eyelids having been noted on the previous day. There was no other abnormality on physical examination. Blood pressure was 125/80 mm. Hg.

Investigations on admission showed marked albuminuria, 900 mg. per 100 ml. There were no pus cells or casts in the urine and only occasional red cells. Haemoglobin was 98% and the blood urea level 40 mg.%, serum proteins 5 g. (albumin 3.2 g., globulin 1.8 g.). The urinary mercury excretion in 24 hours was 460 μg. The normal excretion of urinary mercury is less than 100 μg. in 24 hours (Bidstrup, Bonnell, Harvey, and Locket, 1951).

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By August 21, the oedema had cleared and albuminuria decreased. A further course of $CaNa_2E.D.T.A.$ intravenously in the same dosage as before again increased the urinary mercury excretion. The patient was discharged well, free from albuminuria, some three months after admission. Fig. 1 shows the treatment given and urinary mercury and protein excretion.

Method of Estimating Mercury in Urine

The method used to estimate mercury was that of Rolfe, Russell, and Wilkinson (1955) as given by King and Wootton (1956).

In order to assess the accuracy of the recovery of mercury in the presence of the complexing agents, blank and check estimations were carried out as in the Table.

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*Added as mercuric chloride, as in the standard solution in the method of Rolfe *et al.* (1955).
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These estimations render it unlikely that a low "B.A.L.: Hg" value might have been due to inadequate break-up

concomitant rise in degree of emotional instability with severity.

TABLE 3

LACK OF RELATIONSHIP BETWEEN DURATION OF NYSTAGMUS AND EMOTIONAL INSTABILITY ON HERON TEST I

	Duration of Nystagmus in Years				
	0–4	5–6	7–8	9–10	11 and over
Number of men	6	18	23	9	11
Mean score (Heron I)	7·7	10·4	9·6	10·9	8·5

There was no evidence of any relationship (see Table 3) between emotional instability and duration of the disease.

Discussion

The majority of these tests of emotional instability have shown a significant difference between the two groups, thereby suggesting that men with nystagmus are more emotionally unstable than men without the disease. It should be stressed that this is the first time a study of the disease has been made using carefully standardized tests. All the findings have been based on objective tests and the results confirm the opinion that psychological factors play an important part in the disease.

The results of Heron's test part II (see Table 1), which shows that there is no difference in sociability between miners with nystagmus and controls, agrees with the findings of Browne and Beck (1954). But, whereas they concluded that there was no difference at all between the two groups, it appears that while being as sociable as the controls, men with nystagmus do show other psychological differences.

However, a basic problem still remains: Which appears first, the nystagmus or the emotional instability ? Is it the case, as Culpin (1925) suggested, that the nystagmus is of purely physical origin and itself precipitates a neurosis, or does the neurotic personality predispose a miner to develop the disease ?

Dorothy Campbell (1948) has suggested that the worry and unemployment resulting from nystagmus may encourage the development of neurosis. But, in this study, which was made in a time of almost full employment in the pits, only six of the 67 men with nystagmus were in fact unemployed and therefore the high scores obtained cannot be attributed to the stress of unemployment.

However, it should be pointed out that only two of the men with nystagmus had returned to their original jobs at the coalface, the remainder being employed in surface work at which they were earning approximately half their previous wages. It would be interesting to compare a group of disabled men from another industry, who were similarly earning much less than their original income, and see whether they obtained high emotional instability scores. This would indicate to what extent the instability is caused by the financial stress resulting from nystagmus or indeed any other disease.

The only way to solve the basic problem of which comes first would be a long-term and large-scale investigation in which all men entering the pit would be given these tests, their scores recorded, and several years later an analysis made of the scores of those men who subsequently developed the disease. In this way it should be possible to determine whether the nystagmus superimposed on a latent emotional instability precipitates a neurotic crisis, or if lack of stability is a factor in causing nystagmus.

With greater improvement in lighting conditions in the pits the incidence of nystagmus is declining, nevertheless, the problem still remains as to why some men develop the disease and others do not.

Summary

Sixty-seven men suffering from coal-miners' nystagmus and the same number of control miners were compared on a battery of objective tests of emotional instability.

On four out of six tests the men with nystagmus scored significantly more neurotic responses than the controls. All six tests showed a difference in the expected direction between the two groups. It was found that the men with nystagmus were not less sociable than men without the disease. Neither the severity of the disease nor its duration correlated with emotional instability.

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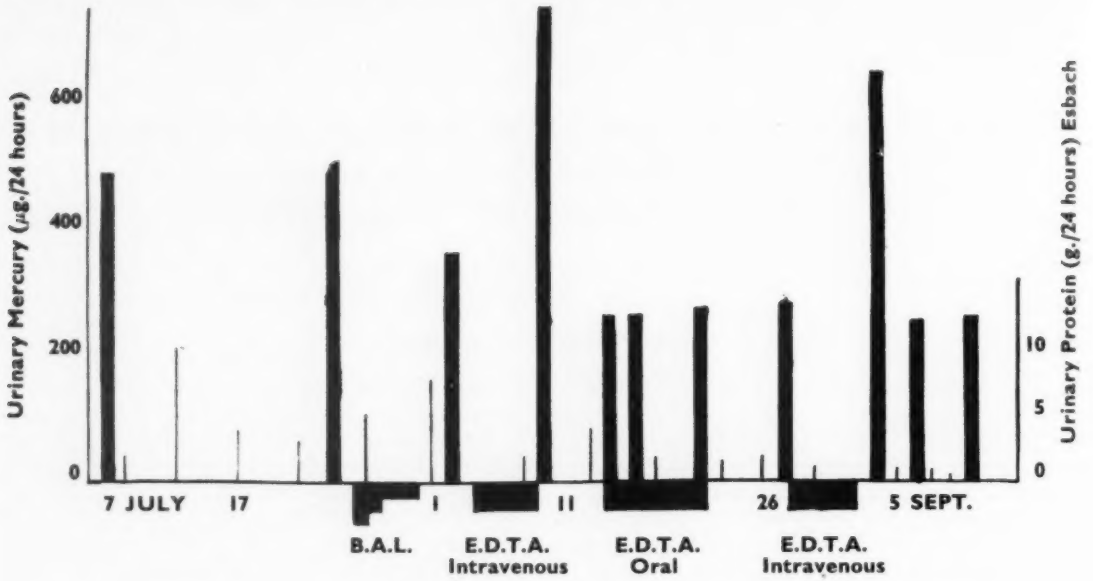

FIG. 1.—Graph showing treatment and excretion of urinary mercury (thick lines) and urinary protein (thin lines).

of the B.A.L.: Hg complex during ashing. The likelihood that a high "$CaNa_2E.D.T.A.$: Hg" value might have been due to inclusion in the analysis results of other metals liberated by $CaNa_2E.D.T.A.$ is also excluded by these estimations.

Comment

This case is reported as it is contrary to the experience of Bell, Gilliland, and Dunn (1955) who found that B.A.L. did increase urinary excretion of mercury in a case of chronic poisoning and that $CaNa_2E.D.T.A.$ did not. Bell *et al.* administered $CaNa_2E.D.T.A.$ intravenously as a 3% solution, giving 2·5 g. daily for five days. They do not state the dose of B.A.L. given. In the present case intravenous $CaNa_2E.D.T.A.$ on two occasions increased mercury excretion while B.A.L. did not. Treatment with B.A.L. was in fact followed by increased albuminuria and some nausea, possibly resulting from a toxic effect of B.A.L. itself (Hunter, 1957).

It is concluded that intravenous $CaNa_2E.D.T.A.$ is of value in the treatment of chronic mercury poisoning.

Summary

A case of chronic mercury poisoning treated with 2 : 3 dimercaptopropanol (B.A.L.) and intravenous calcium disodium versenate ($CaNa_2E.D.T.A.$) is reported.

Contrary to previous reports, $CaNa_2E.D.T.A.$ resulted in increased urinary excretion of mercury, while B.A.L. did not.

It is concluded that $CaNa_2E.D.T.A.$ is of value in the treatment of chronic mercury poisoning.

I thank Dr. G. Riddell Royston for permission to publish this case. I acknowledge gratefully the help given by Mr. Winks of Barnet General Hospital, who did all the mercury estimations.

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A CASE OF BERYLLIUM DISEASE

BY

C. H. WOOD, K. P. BALL, and N. DONALD TEARE

From the Rockefeller Unit of Occupational Health, London School of Hygiene and Tropical Medicine, the Central Middlesex Hospital, and the Department of Pathology, St. George's Hospital, London

(RECEIVED FOR PUBLICATION FEBRUARY 13, 1958)

Beryllium disease was first described in 1933 by Weber and Engelhardt working in Germany, and has since been reported from many other countries. In Great Britain it is rare, but in the United States of America more than 500 cases have been reported. Seventy-five per cent. of these cases arose in beryl smelting plants and during fluorescent lamp manufacturing where, for a time, a phosphor containing 13% beryllium by weight was used.

The three principal syndromes of the disease, namely, chronic pulmonary, acute pulmonary, and dermal, have been described in patients in this country (Agate, 1948; Royston, 1949; Lederer and Savage, 1954; Sneddon, 1955; Rogers, 1957). The reported incidence of the chronic pulmonary type of disease has been low possibly because, in the absence of epidemiological evidence, it is not suspected. A further difficulty is the absence of good diagnostic tests that can safely be applied. The first patients who had this form of beryllium disease in the U.S.A. were diagnosed as sarcoidosis, miliary tuberculosis, or silicosis until the true nature of the condition was recognized.

The case now reported is believed to be one of chronic beryllium disease, although the histological findings are not entirely typical. The history of a mixed exposure to coal dust, mesothorium, and silica illustrates some of the difficulties of investigation and diagnosis in this type of case.

Case Report

In May, 1951, a chemical worker, aged 36, was admitted to hospital with a diagnosis of bronchopneumonia.

Occupational History.—From the age of 14 to 18 he worked underground in a Nottinghamshire coal-mine and then went into domestic service for five years. At the age of 23 he went to work for a small chemical firm where he stayed 11 years and was exposed to a variety of toxic substances. For the first three years (aged 23 to 26) he was making granules for absorbing toxic gases. He had to grind silica gel in hand-operated coffee mills. This was a very dusty process. During this time he also had contact with cement, barium hydrate, and zinc chloride and was extracting mesothorium. The latter became his main occupation for the next three years (aged 26 to 29). Aged 29 to 34 he was making a fluorescent powder for tubular lights. He collected beryllium oxide from a ball mill, mixed it with silica gel and heated it to 1,200 to 1,800° C. After firing he tipped the mix into bins, broke up the lumps by hand, sieved it, and then tipped the powder into bags. In 1949 he left this job because of shortness of breath and general malaise and worked as a clerk for a year.

Medical History.—In 1943, at the age of 28, he developed painful indolent ulcers on his arms and legs. These were attributed to mesothorium. In 1946, after he had been working with beryllium oxide for two years, he began to get short of breath. This increased and he developed a dry cough. By 1950 a chest radiograph showed "diffuse reticulation throughout both lung fields, increasing towards the lower zones with some fine nodulation".

He was admitted to hospital in May, 1951, having spent most of the previous year in bed. He had lost 2½ st. in weight. He produced 2 to 4 oz. of sputum daily and was dyspnoeic on the slightest exertion. He had a low-grade fever. On examination he was thin and cyanosed, and his fingers were grossly clubbed. Fine rales were present in all areas of the chest. Scars of the ulcers could be seen on his arms and legs.

Investigations.—A blood count gave Hb. 102%; white cells 13,500 per c.mm.; E.S.R. 42 mm. in one hour (Westergren); serum protein 7·0 g. per 100 ml. Vital capacity was 1,420 ml. A radiograph of the chest at this time showed extensive reticulation throughout both lung fields with early nodulation (Figs. 1 and 2). Analyses of 24-hour specimens of urine were performed on 13 occasions during his stay in hospital. On two occasions 5·8 and 4·5 μg. of beryllium were found; on four occasions, though detected qualitatively, the amount was below the level of quantitative estimation (0·7 μg. per 24-hour specimen) and on seven occasions no beryllium was found.

Progress.—During the first few weeks in hospital he improved only slightly. He was given streptomycin

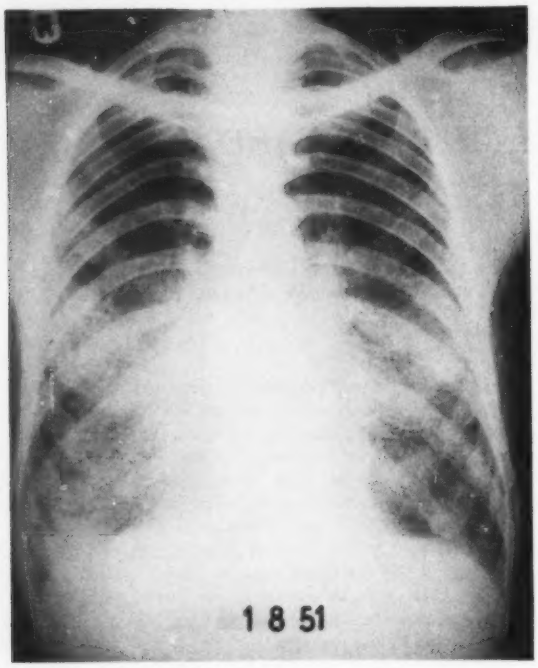

FIG. 1.—Chest radiograph in May, 1951, the patient aged 36, showing extensive reticulation and early nodulation.

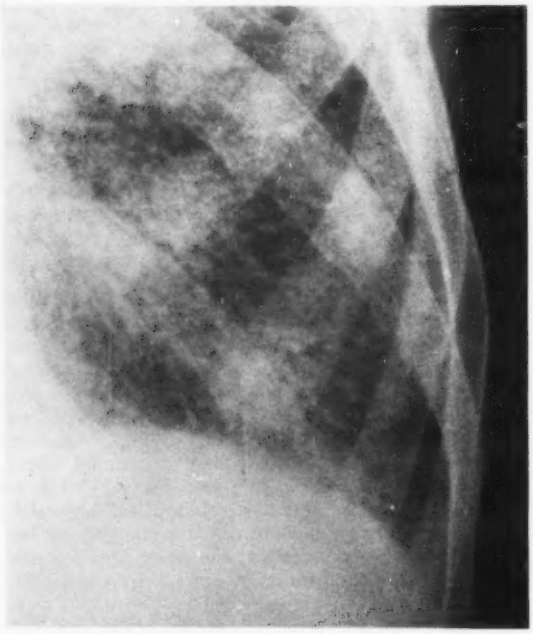

FIG. 2.—An enlargement of the left lower zone from Fig. 1.

penicillin, and chloramphenicol with little decrease in the amount of sputum.

He was then started on corticotrophin, 20 mg. six hourly. Three days later he could talk and move about in bed without gasping. There was a marked improvement in his appetite. After one week his sputum was greatly reduced and he could walk for 300 yards. Improvement continued for three weeks and his condition then remained stationary. His vital capacity had risen from 1,420 ml. to 2,300 ml. After five weeks corticotrophin was stopped (total given 1.68 g.). During the next four weeks he became steadily more dyspnoeic. A further course of corticotrophin was started and the dosage gradually increased to 150 mg. day but no further improvement occurred. After 27 days, treatment was again stopped (total given 2.01 g.) and he was discharged.

During the next four years he remained completely disabled. He complained of a feeling of severe fatigue and his breathlessness was such that he was seldom able to leave his bed. He had a troublesome cough. He was treated to relieve bronchospasm and to prevent infection, but this did not affect the progress of the disease. Chest radiographs showed an increase in the nodulation and he developed right heart failure from which he died in September, 1955.

Necropsy.—The body was poorly nourished and there was marked clubbing of the fingers.

The pertinent internal findings were an excess of free fluid (4 oz.) in the pericardial sac and a dilated and thickened right ventricle, which was tough and firm. The peritoneal cavity contained 1 pint of fluid and the liver had the typical nutmeg appearance of chronic congestion. The other organs showed no significant changes. Microscopical examination of brain, kidneys, and adrenal tissues showed congestion in the small blood vessels. In the liver chronic congestive changes were well marked with the appearances of early cardiac cirrhosis.

Lungs.—Scattered adhesions were present over the posterior aspects of both lungs and there was a little free fluid within the pleural cavities. The lungs showed a gross degree of emphysema (Fig. 3) and their substance contained numerous hard, shotty nodules, maximal in their posterior halves, with bronchopneumonia in both lower lobes.

The lung sections showed an overall picture of acute congestion, small areas of pneumonic consolidation and lakes of fibrin together with emphysema. The outstanding feature was the presence of numerous small nodules composed chiefly of mononuclear cells of endothelial type with an intermingling of plasma cells and lymphocytes. No caseation was seen. Giant cells of both Langhans and foreign body type were present in moderate numbers with inclusion bodies, both within the giant cells and extracellularly in the granulomatous areas. The inclusion bodies were seen both as long refractile needles and as conchoidal bodies, the latter consisting of a central body of irregular shape which was either a deeply stained amorphous mass or colourless plates not refractile to polaroids (Fig. 4). Towards the central body there was a series of concentric lines, the outer line being

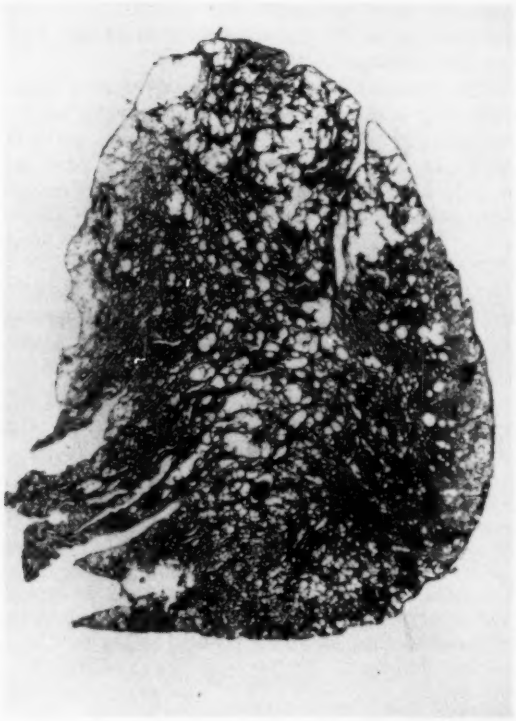

FIG. 3

FIG. 3.—Whole section of left lung showing widespread emphysema and consolidation in the lower zone. (Prepared by the method of Gough, James, and Wentworth, 1949.)

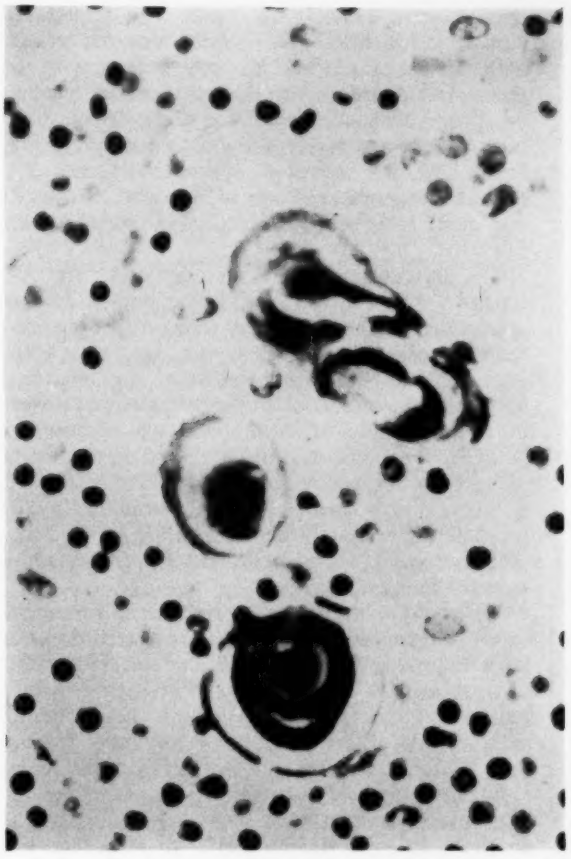

FIG. 4

FIG. 4.—Part of a nodule showing typical conchoidal body, surrounded by mononuclear cells × 600.

heavy and the inner ones thinner. When these bodies were digested by hydrogen-peroxide and stained for the presence of calcium and iron they gave positive reactions.

Fibrosis was not a feature, which is perhaps surprising in view of the length of the clinical history. Sections of lymph node showed discrete areas of hyalinization and fibrosis together with scattered conchoidal bodies. The other tissues examined microscopically showed no evidence of involvement.

The histopathology, as described, is that of a diffuse and focal chronic sarcoid-like pulmonary granulomatosis similar to that seen in cases of chronic beryllium disease as described by Dutra (1948).

Chemical Analysis.—Chemical analysis of a sample of lung showed a concentration of 0·22 g. of silicon dioxide per 100 g. of dry lung. This figure is slightly above the normal but does not approach the amounts which are found in silicosis (King, Maguire, and Nagelschmidt, 1956). No beryllium was detected.

Discussion

One of us (C. H. W.) has recently had the opportunity of examining the records of over 500 American cases, including 300 chronic cases, which are being collected in a beryllium case registry by Dr. Hardy at the Massachusetts General Hospital. The clinical features of the case described were indistinguishable from those of the severe cases of the chronic pulmonary syndrome recorded in the beryllium registry.

By the nature of the processes for which beryllium is used, there is frequently a history of exposure to other hazards at the same time, such as silica and gamma radiation. The striking similarity of the clinical picture of these cases occurring in beryllium workers engaged in different processes is an important diagnostic feature. Proof of the diagnosis may be impossible. The discovery of beryllium in the urine is evidence of exposure to beryllium but not of disease: many beryllium workers excrete beryllium in their urine for years without developing any disease. Acting on the principle that beryllium disease is an allergic response to beryllium or a beryllium-protein allergen, patch testing has been

tried (Curtis, 1951). De Nardi, Van Ordstrand, Curtis, and Zielinski (1953) claim consistent results with this diagnostic test; but others, in view of the theoretical danger of producing a severe reaction or of provoking an exacerbation of the disease, have been reluctant to perform this test. Sneddon (1955) found that, for several days after patch testing a patient, dyspnoea appeared to be worse than usual and moist rales were heard over both lungs for the first time.

The demonstration of a granulomatous reaction together with the presence of beryllium in biopsy and necropsy specimens has sometimes supported the diagnosis. Possibly however, once the pathological process has been initiated, the offending agent may disappear. Also the difficulties of detecting trace quantities of beryllium are considerable and complete reliance should not be placed on the results of such examinations, especially when performed only on rare occasions. In this case the microscopical picture was one of chronic sarcoid-like granulomatosis, but no beryllium was found in the sample of lung analysed.

The rapid subjective and objective improvement of the patient with corticotrophin was striking. Relapse followed withdrawal and a subsequent course of treatment for 27 days failed to produce a further remission. The fatality rate among those patients with chronic beryllium disease reported to the case registry has fallen during the past eight years. While this may be due, in part, to the more frequent diagnosis of milder cases now that the syndrome is better known, Hardy (1955) believes that the introduction of steroid therapy is also important. There were only two deaths among 101 patients treated with steroids between 1950 and 1955. In many of these, treatment was started earlier than was possible in the patient described in this paper and was continued for several years.

The potential field of usefulness for beryllium is expanding and opportunities for exposure exist in this country. Further sporadic cases or small outbreaks are therefore still possible and will provide a challenge for diagnosis if they cannot more properly be prevented.

Summary

The occupational and clinical histories and post-mortem appearances of a man who developed dyspnoea and cough while working with beryllium oxide are reported. The disease progressed, and, despite a temporary remission under treatment with corticotrophin, he died at 40 years of age after having been bedridden with dyspnoea for four years.

Some of the difficulties of confirming the diagnosis of beryllium disease are discussed.

We wish to thank Dr. P. L. Bidstrup for her advice in the clinical management of the case; Dr. J. A. Bonnell for the beryllium analyses; and Dr. W. Jones-Williams for the whole lung section reproduced in Fig. 3.

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BOOK REVIEWS

Safety in the Chemical Laboratory, 2nd edit. By H. A. J. Pieters and J. W. Creyghton. (Pp. 305. 40*s*. $7.50.) London: Butterworths Scientific Publications; New York: Academic Press. 1957.

Much has been written on the general problems relating to personal safety but little has been directed to schools, technical colleges, universities, and indeed industrial establishments where laboratory work is carried out. The authors of this book are to be congratulated on bringing so much valuable information into such a small space and they stress, and rightly so, that " the book should be used on the laboratory bench and not in the library ".

The first chapters deal with the general considerations of safety, fire hazards, dangerous substances and explosives. There is an excellent chapter on the physiological effects of chemical substances, dealing with respiration, the mode of entry of poisons into the body and their method of action. Special attention is paid to methods of handling toxic substances and the nature and action of toxic dusts and gases.

The subject of protective devices and first aid is very adequately dealt with both in Chapter 9 and in the tables at the end of the book. One of the problems which confronts those who are responsible for general management is that of analytical procedures relating to toxic and hazardous substances. The authors have devoted, and rightly so, over 60 pages to this important subject.

The book is unusually well written, it is clear and concise, and should find a place not only on every laboratory bench but also in every library. This is a book which can be thoroughly recommended.

A. J. Amor

Bus Workers in their Later Lives. By F. Le Gros Clark. (Pp. 26. Limited number of copies available free of charge from the Nuffield Foundation.) London: Nuffield Foundation.

It is unfortunate that ageing, being a gradual process, produces no clear lines of demarcation; as a result, it can best be measured by the subjective feelings of the patient rather than the objective findings of a medical examination. A man's assessment of his personal disablement due to age tends to be based on several factors, not all of them medical or physiological. Relevant factors include the satisfaction derived from his job, financial needs, the health of his family, and other purely domestic matters. Two men, to all intents and purposes identical, have very different assessments of identical disabilities. Assuming that the number of cases reviewed is large enough, most of the variables mentioned cancel each other out, but the number required to do so must be very large. The report of Le Gros Clark and his colleagues is valuable in that it provides a guide to what has happened amongst a group of men, and as such it gives an indication as to what is probable amongst any similar group. If the conclusions are to be applied to industry in general it is unfortunate that conditions have not remained uniform throughout the period of employment of the men under review. Productivity has been increased in the operation of buses by increasing the capacity and speed of the vehicles, both factors which demand more physical effort from conductors. Thus the process of ageing has been accompanied by more strenuous work, which is the reverse of what has occurred in most industries. It was not until after Le Gros Clark's study had been made that the issue of labour-saving ticket machines assumed any great proportions. No differentiation is made between bus and tram conductors. The final transfer of all tram conductors to buses was completed during the period under review and ex-tram conductors not infrequently complain of the vibration of buses. This can only be explained by the two vehicles having different effects upon joints and their supports. Furthermore, in their final years the trams tended to be less used by the public, so that transference to bus conducting also meant an increased number of passengers with which to cope. If ex-tram conductors form a large proportion of those leaving the service, wrong conclusions may be drawn. So far as drivers are concerned, the job has probably become somewhat easier in spite of the increased speed and traffic congestion. Before the War a busman's wages were high compared with other industrial workers. After the war the reverse was the case and particularly so in the early 1950s. Furthermore these latter years were easy ones in which to obtain other employment. The period under review was therefore one in which the advantages of leaving appeared brightest.

The suggestion that transfer to country areas would provide easier working is interesting but probably unreal. In some of the older market towns near London conditions are worse than in the suburbs. Many older men tend to choose their routes rather than garages and base their choice largely on the times of the first and last buses. This may be due to the need of the wives for companionship in later years when children have left home or it may be due to the high incidence of bronchitis and rheumatic conditions in older people, both conditions which are aggravated in early morning and late evening. It might be well worth while to follow up this study with one of staff on routes which are known to be popular with older men. The survey is most useful and one which can only be criticized in minor details.

J. Fairlee

Gastric and Duodenal Ulcer: A Modern Industrial Problem. Report and Recommendations. (Pp. 6. 1*s.* 6*d.*) Issued by the British Council for Rehabilitation, London. 1957.

This booklet contains the report and recommendations of a working party on the gastric problem in industry set up in 1955 by the British Council for Rehabilitation. The terms of reference were:

> " To consider the problem of peptic ulcer in industry. To examine the possibilities for research work being done in this field, which might include the results of efficient early treatment, the working capacity after partial gastrectomy, and the determination of the benefits derived from special dietary facilities in canteens."

The Chairman of the Group was Dr. F. Avery Jones, one of the most experienced gastro-enterologists in Europe. Working with him were several medical men associated with industry and a member of the Trades Union Congress. It is interesting to note that the British Dietetic Association was also represented.

Although at first sight the terms of reference appear to be somewhat ill-defined, the working party interpreted them correctly as an instruction to produce a short authoritative and well-balanced report which could be easily read and understood by all those interested in the welfare of the industrial worker.

The report concludes that it is both undesirable and unnecessary to exclude anyone with peptic ulceration from employment in industry. This is a bold statement and even in these days of enlightened personnel management will not always be easy to implement. The opinion is expressed that much can be done by good personnel management to help people suffering from peptic ulcer to remain at work. Particular care must be given to the needs of individual sufferers, especially as regards their working conditions and feeding facilities. While most readers will agree with this view, some will feel that it would have been more complete had mention been made of the need for a close liaison between management, however much enlightened, and the industrial medical officer.

No new scientific data have been described but it is obvious that the results of modern thought and research on the subject have been an important influence in the final preparation of the report. The avoidance of physical fatigue and mental strain are stressed as an important factor in preventing recurring attacks of peptic ulceration. Practical suggestions in this connexion have been laid down. It is particularly satisfactory to note that smoking, alcohol, and aspirin are mentioned as aggravating factors and important elements in the prevention of healing of an ulcer.

The problem of shift working is discussed in some detail and the report makes it clear that such work need not be harmful to those with peptic ulceration, provided the shifts are regular and the change-over not too frequent; and also provided that adequate canteen facilities are readily available.

In a restricted but responsible way mention has been made of surgical treatment, and it is pointed out that in those cases selected for surgery the individual is usually restored to full working life and able to eat normal food again. It might have been useful and have completed the picture if readers were informed that the number of cases selected for surgical treatment was on the increase.

Taken as a whole, this report is a useful contribution to lay understanding of peptic ulceration as it affects the worker in industry.

J. SHARP GRANT

Report of the Committee of Inquiry on The Rehabilitation, Training and Resettlement of Disabled Persons. (Pp. 126. 5*s.* 6*d.*) London: H.M. Stationery Office, Cmd. 9883. 1956.

The Committee, which was appointed in 1953, with Lord Piercy as Chairman, to review in all its aspects the existing provision for the rehabilitation, training, and resettlement of disabled persons, has now published its findings as a comprehensive account of the services which a disabled person may now expect to receive under the welfare state, and makes some 46 recommendations. The report will be of interest to all who are concerned with treatment and in particular to those who are practising medicine in industry.

The public conscience has become increasingly alive to the needs of the disabled and this is in no small part due to the initial efforts of voluntary organizations. The valuable contribution which these organizations can continue to make should, in the opinion of the Committee, receive careful consideration.

It was found that no national figures were available to provide an accurate assessment of the size of the problem. This may explain the exaggerated claims which are occasionally made for the provision of additional facilities. It is suggested that the medical profession as a whole has failed to realize the scope and potentialities of effective rehabilitation or to use to the best advantage existing techniques and facilities.

The Committee appears to agree that rehabilitation is essentially a medical problem and should at all stages be under medical control. Emphasis from the initiation of treatment should be on the restoration of working capacity and the goal of all treatment is return to work and a normal way of life. An effective programme must extend far beyond the field of physical medicine and should be based on work of therapeutic value, if at all possible within the framework of industry.

An interesting recommendation is that comprehensive centres should be established on an experimental basis to maintain the principle of continuity, and to provide facilities for hospital rehabilitation, industrial rehabilitation, and assessment of capacity on one site. The fact that an experiment on somewhat similar lines has been already carried out in this country seems to have escaped the notice of the Committee.

The need for a closer link between the hospital service and industry is appreciated. There is little doubt that liaison with industrial medical officers could help to bring this about. General practitioners are urged to take on fuller responsibilities and to make greater use of

existing facilities to meet the needs of temporarily or permanently disabled patients.

Local authorities were given wide powers to promote the welfare of the disabled by the National Assistance Act of 1948, but comparatively few have taken advantage of these powers. The use of " work aids " is discussed and the cooperation and ingenuity of industry in providing these is commended.

The Committee supports the quota scheme for the employment of disabled and refutes the suggestion that their apparent segregation is undesirable. This is contrary to the opinion of Hanman and others in the United States. Assessment of capacity is stated to be a medical responsibility and it is presumed that this refers to physical capacity and the part which the doctor plays in placement in industry. Attention is directed to the role of the Disablement Resettlement Officer and the need for careful selection and suitable training for this important post is stressed.

The difficulty of obtaining remunerative employment for the severely disabled is recognized, and the recommendation that transport should be provided for these workers is practical.

The Committee do not consider that much in the way of additional capital expenditure is required. Apart from the experimental centres to which reference has been made. it is urged that all major hospitals should establish resettlement clinics, that hostels for the disabled should be provided, and that there should be an expansion of the welfare services of local authorities.

The report is certainly comprehensive though its length may defeat the object of ensuring greater knowledge of the wide range of services. While all may not agree with certain recommendations, the Committee are to be congratulated on the production of a report which must have entailed much work and which clearly demonstrates that this country leads the world in this important branch of social service.

A. AUSTIN EAGGER

The Treatment of Fractures, Vol. 11. By Lorenz Bohler. (Pp. viii+438; 941 figures. $17.50.) London and New York: Grune & Stratton. 1957.

The second volume of this well-known work deals with injuries around the hip and fractures of the femur. The subject matter is very fully discussed in the 430 pages and is illustrated by a wealth of radiographs, photographs, and diagrams. Every aspect of these injuries has been covered. The author has obviously intended that the book should be used for reference by all members of a fracture unit; for instance, we find detailed lists of material and instruments required for the application of a hip spica; facts which are more necessary to the plaster sister than for the orthopaedic surgeon. Also, the questions which follow each section of the book are much more reminiscent of a cram book for the medical student than a specialist textbook. The practising fracture surgeon would be inclined to consider Prof. Bohler rather too verbose on some of the more archaic methods of treatment; 17 pages devoted to the treatment of fractures of the neck of the femur in a Whitman plaster may be of historical value, but are hardly of any practical use. There are several similar examples which obscure the really valuable information.

Despite these criticisms the book remains a valuable study of femoral injuries and will continue to hold its place as one of the foremost works of reference.

J. N. WILSON

I Fondamenti Igienico-Fisiologici della Illuminazione Razionale. [Le relazioni tra illuminazione e visione.] (Physiological bases of rational lighting as a hygienic measure.) By Antonio Tizzano. Roma: Edizioni E.N.P.I. 1956. (Pp. x+75; 53 figures. L.1,200.-.) 1956.

The present era of high-grade precision work in a wide variety of industries has brought a realization that light is one of the most essential factors in efficient and accurate work. On this level the proposition is soon apparent even to refractory minds, but it should be no less apparent to employers and managers in all industries. The standards laid down by law are minima and do not sufficiently impress the great effect of a pleasant and bright ambience on the contentment, liveliness, and effectiveness of workpeople. In the words of the well-known authority, Weston, the law sets " a limit to the dimness allowable ". All too frequently the factory or workshop presents far too dim and gloomy an atmosphere, a situation which is, in most cases, readily remedied often at little expense. Expenditure or not, however, the provision of adequate general lighting combined with local lighting, which permits good visibility without strain at the working point is a requirement to which every workman has a right. The problem varies in different industries and calls, in the more difficult instances, for specially expert advisers since no universal standard can be laid down. But there are general physiological principles which relate visibility to illumination which should be understood by all medical personnnel in industry.

Dr. Tizzano has, in the present little volume, given a quick but valuable review of present knowledge on this matter. There were and still are many difficulties. The scrambling growth of industry soon blocked out even the proper use of the best of all sources of light by design and congestion of buildings, hopeless ill-supply of window space, and accumulated opacity of even such windows as there were. In modern times sustainable excuse remains neither for industrial gloom, nor for lack of information, especially in the minds of medical men and women in industry, on the various lighting codes which have been worked out.

Tizzano, himself a contributor to modern techniques of industrial illumination has, in this work, given the principles, based on results obtained mainly in the last 20 or 30 years, especially in Britain and America, which must be understood in order to build up a rational lighting system for any industrial operation. Starting from the prime factor of visual acuity (power to distinguish test objects of known size at known distances or, quantitatively, the reciprocal of the angle subtended at the eye by the smallest test object distinguished) and those influencing it (contrast, seeing time, luminance of the background), the author proceeds to the most important

adjuvant factors of age, direct glare (ratio of the luminance of the immediate background to that of the surround or, qualitatively, the irritating direct intrusion of surround luminances into the field of vision), indirect reflected glare (reduction of visibility at the working point by intrusion of luminances from reflecting surfaces, *e.g.*, from the work object itself or from the immediate background; determination of zones of potential indirect glare is largely a matter of geometry), choice of diffuse or direct lighting (play of shadows can produce an apparent change in visibility of solid objects), background structure or design which can diminish the visibility of objects and, finally, the colour of object or background.

The review of these aspects of seeing is given with a strongly physiological and erudite flavour, richly illustrated with graphs and diagrams taken from or adapted from the original papers. It calls for slow study with careful digestion of the meaning of each point made; the graphical method will, if this is done, be found to imprint principles in this form more readily than words.

The older view that above a certain luminance no further increase of acuity is obtainable has been known for a good many years to be in error for, given a constant contrast and sufficient visual time, two-point discrimination increases asymptotically with increase of luminance, the limiting visual angle being about 0·406 ft. at about 1,400 foot-lambert. As stated by Moon and Spencer (1944), the higher the luminance the better the vision. This proposition completes the process of correction of the findings of König in 1897 which was started by Lythgoe about 1932 and which gives the final justification of the almost obvious fact that the best illumination for visual work is daylight (up to 1,000 foot-lambert at its best).

For practical purposes the advantage gained from increases at very high luminance is very small as is readily seen from the empirical equation $\alpha = \alpha_\infty \left(1 + \frac{K}{B_N^1}\right)^n$ when K and n are constants and α_∞ is the limiting value of α as B, the luminance, approaches infinity. Nevertheless, the great effect of increased luminance in augmenting visual acuity in wearers of spectacles and in older workers (presbyopia and diminished size and variability of pupil) must not be overlooked.

One aspect to which we would direct the attention of medical officers is that of the time taken to recognize an object, the reciprocal of which may be called velocity of vision. The workman being quite likely, in an ordinary non-quantitative test, to give an affirmative answer without regard to the time taken to recognize the test object (*i.e.*, to the subjective effort he will experience), it should fall to the medical examiner to make objective measurements of it in the conditions of size of object, luminance and contrast obtaining.

It is a pleasure to observe that full justice is done in this review to the outstanding work of Lythgoe and of Weston, one of the well-known nomograms constructed by the latter being given in modified form for determining the intensity of illumination required for different percentages of maximum visibility defined by size of object, distance from the eye, visual angle, and contrast between object and background.

For those who wish to enter the more erudite fields of industrial medicine this review could serve as an introduction to one aspect of it and could stimulate the younger recruit with a research bent to adopt it. [1 foot-lambert = the objective measurable brightness of a perfect diffusing surface emitting 1 lumen per square foot. 1,000 foot-lambert = 2·1/3 candles per square inch.]

M. W. GOLDBLATT

Books Received

(Review in a later issue is not precluded by notice here of books recently received.)

Recent Outbreaks of Infectious Diseases. By S. Leff. (Pp. ix + 408. 35*s*.) London: H. K. Lewis. 1957.

The Index of Technical Articles, No. 2, March, 1957. (Pp. 90. Subscription £6 6*s*. per annum.) London: Iota Services.

Report on the Health of the Royal Air Force and the Women's Royal Air Force for the Year 1953. [Air Ministry—A.P. 3319/53.] (Pp. 91.) London: H.M. Stationery Office. 1957.

International Comparison of Unemployment Rates (reprinted from *The Measurement and Behaviour of Unemployment*, Reprint No. 86. A Report of the National Bureau of Economic Research). By Walter Galenson and Arnold Zellner. (Pp. 439-583.) Berkeley (California): Institute of Industrial Relations. 1957.

Central Mining—Rand Mines Group. Health Department **Report for the Year 1956.** (Pp. 24.) Johannesburg: Rand Mines Ltd. 1957.

Tata Industrial Health Refresher Course, 1956. (Pp. 19; illustrated.) Tata Industries Ltd. 1957.

Particulate Clouds: Dust, Smokes and Mists. By H. L. Green and W. R. Lane; Foreword by Sir Harold Hartley. (Pp. xix + 425; 8 plates and text figures. 70*s*.) London: E. & F. N. Spon. 1957.

Precancerogenesi e tumori professionali, Vol. II. By G. A. Chiurco. (Pp. xvi + 1268; illustrated. Lira 10,500.-.) Rome: Istituto Nazionale per l'Assicurazione contro gli Infortuni sul Lavoro. 1956.

Ergonomics: Human Factors in Work, Machine Control and Equipment Design, Volume I, No. 1, November, 1957. Edited by A. T. Welford. (Pp. 100; illustrated. 25*s*. per part; Sub.: £4 15*s*. per volume.) London: Taylor & Francis. 1957.

Chronic Bronchitis, Emphysema, and Cor Pulmonale. By C. H. Stuart-Harris and T. Hanley. (Pp. 252; 61 figures, some in colour. 42*s*.) Bristol: John Wright. 1957.

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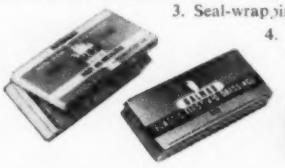

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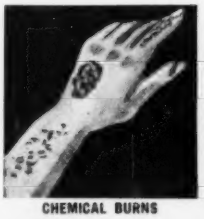
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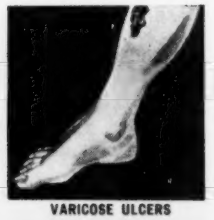
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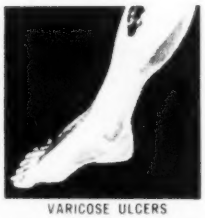
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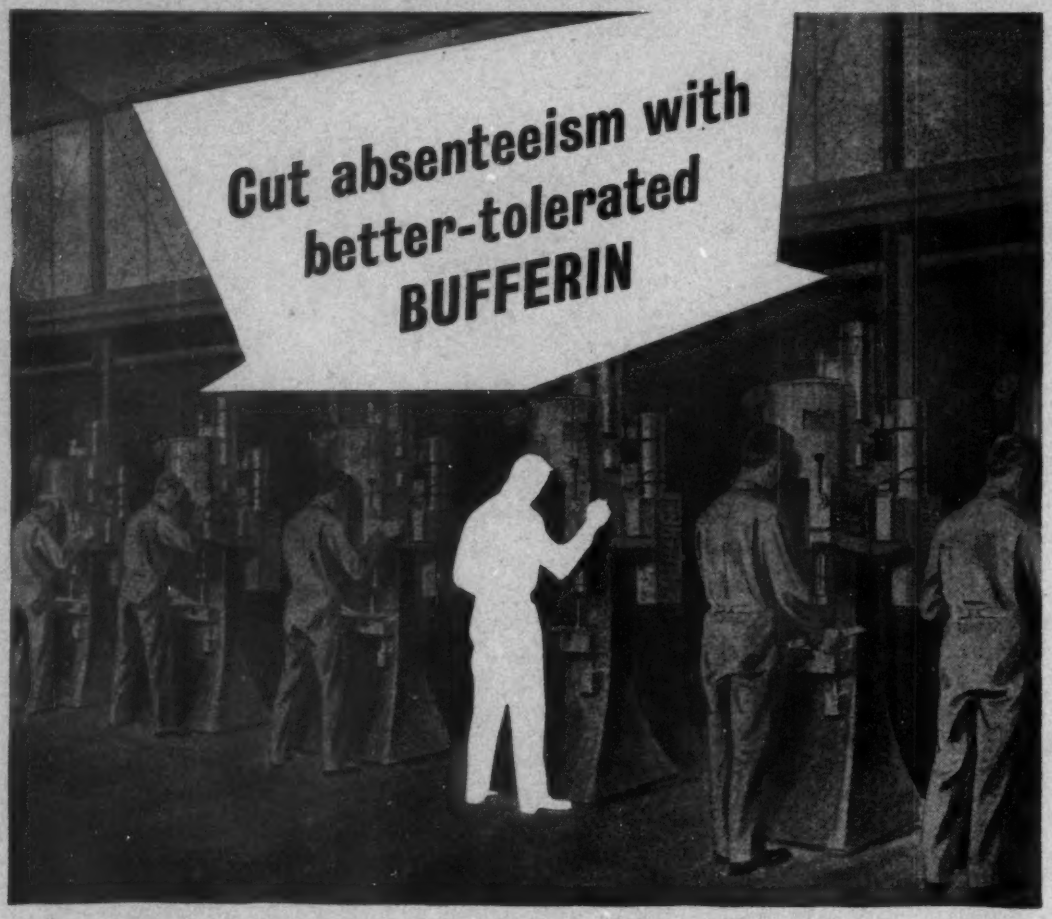

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